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APPLIED MECHANICS REVIEWS

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THE SLIP LINES AND SLIP SURFACES IN THE THEORY OF PLASTICITY AND SOIL MECHANICS

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1. GENERAL CONSIDERATIONS AND HISTORICAL REVIEW

The theory of slip lines and slip surfaces has found a vast extension in the solution of many important problems of the theory of plasticity, of forming and processing of metals and of the limit equilibrium of soils. The rise of slip lines and slip surfaces along which the slip of material occurs characterizes the plastic state or the limit equilibrium of continuous media.

The first studies of slip were made in soil mechanics. The basis of slip theory has been created by C. Coulomb (5) and by his successors W. Rankine (50) and M. Lévy (30). Only later were the slip lines discovered in soft steel by Lüders (39). L. Hartman (19) appears to have been the first to study more in detail these lines in metals.

The importance of slip lines and slip surfaces for the theory of plastic state of metals and for mechanics of limit equilibrium of soils was recognized by Otto Mohr (36, 39), who has derived the slip theory of strength. According to Mohr, the shearing stress on the slip surfaces depends only on the value of the normal stress acting in the same point of the slip surface.

The condition of strength or of plasticity may be in this way represented by the limiting curve which is the envelope of all largest principal Mohr stress circles. The points of tangency of the major stress circles along the enveloping curve $\tau_n = f(\sigma_n)$ represent in their abscissas σ_n and ordinates τ_n the normal and the shearing stress on the surfaces of slip.

The strength or plasticity respectively of different sorts of materials is characterized by different types of limiting Mohr envelopes. In the case of ideally plastic materials, the limiting Mohr envelope consists in the range of compression, and partially also in the range of tension, of two parallel straight lines

$$\tau_n = \text{const}, \qquad [1]$$

expressing the maximum shearing stress condition which is in some way identical with that derived by the French engineer Tresca (67) from the observations made in the course of extrusion tests on the flow of soft metals through orifices. According to Mohr and Tresca, the slip lines are inclined at an angle of 45 deg with respect to the direction of the largest and smallest principal stress.

In the case of loose and cohesive-loose materials with the angle of internal friction φ and with the normal cohesion σ_c, the limiting Mohr envelope is composed from two inclined straight lines given by the following equations

$$\tau_n = (\sigma_n + \sigma_c) \operatorname{tg} \varphi. \qquad [2]$$

In the general case, the limiting Mohr envelope is a continuous curve for which Z. Sobotka (55) has derived the limiting-state condition in the form of power function

$$\tau_n^m = \frac{m}{2^{m-1}} \sigma_{md} (\sigma_n + \sigma_c) \sin^{m-2} 2\nu_d \cos 2\nu_d, \qquad [3]$$

where σ_{md} is the limiting compressive stress, σ_c the cohesion stress and ν_d the angle of slip lines with the maximal principal stress in the case of simple compression. Another form (55) of the general limiting curve may be given by the following infinite Fourier series

$$\tau_n = \sum_{k=0}^{\infty} A_k \sin \frac{(2k+1)\pi\sigma_n}{\sigma_0}. \qquad [4]$$

Whereas formerly the investigators studied the slip in isotropic and homogeneous materials, recently, the general trend has returned to the investigation of slip fields in nonhomogeneous and anisotropic media. For this purpose, in the first place, the derivation of the slip condition taking the nonhomogeneity into consideration was needed. The problem of orthogonal anisotropy (orthotropy) of homogeneous bodies was investigated by R. Hill (23). The general theory of limit-state conditions of plasticity for orthotropic and nonhomogeneous materials was derived by W. Olszak and W. Urbanowski (42) and for anisotropic nonhomogeneous media by W. Olszak, P. Perzyna and C. Szymański (43). Z. Sobotka (55, 56, 57) has formulated the special conditions of plasticity for nonhomogeneous bodies sensible to hydrostatic pressure.

Mohr's theory is developed conforming to the course of slip lines and slip surfaces. Mohr has formulated rules for defining surfaces of slip under very general properties of materials. Nevertheless, this theory includes some incompleteness in the treatment of the limiting condition, which consists especially in neglecting the influence of the intermediate principal stress at the three-dimensional state.

This influence is considered in the equation of general limiting surface of yielding or of strength respectively, which has the following form

$$f(\sigma_1, \sigma_2, \sigma_3) = 0. \qquad [5]$$

This condition may be formulated by referring it to the octahedral planes of the stress tensor as follows (39)

$$\tau_{oct} = f(\sigma_{oct}), \qquad [6]$$

i.e. for isotropic materials

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = F\left(\frac{\sigma_1 + \sigma_2 + \sigma_3}{3}\right). \qquad [7]$$

The preceding equation represents a surface of revolution in a system of rectangular coordinates, whose axis is equally inclined with respect to the coordinate axis σ_1, σ_2, σ_3.

In a special case, if the function on right side of Eq. [7] is constant, the limiting surface became a straight circular cylinder representing the condition of constant strain energy of distortion, derived by M. I. Huber (26), H. Hencky (22) and R. von Mises (34).

The limiting surface corresponding to Mohr's theory consists of six partial surfaces and has hexagonal cross sections. If the shear stress on slip lines is constant, the limiting state of the anisotropic media and of the materials of unequal mechanical properties in compression and extension has an irregular shape. Recently, R. M. Haythorthwaite (20, 21) has derived a special yield criterion for ideally plastic materials and for sands and represented it by the limiting surface of the triangular cross section.

The limiting condition may be expressed also by means of plastic potential corresponding to the strain energy, derived by R. Mises (35), and formulated for anisotropic and nonhomogeneous materials by W. Olszak, W. Urbanowski, P. Perzyna and C. Szymański (42, 43) as follows

$$\Psi_\sigma = \tfrac{1}{2} H_{\varkappa\lambda\mu\nu}(P)\sigma_{\varkappa\lambda}\sigma_{\mu\nu}, \qquad [8]$$

where $H_{\varkappa\lambda\mu\nu}(P)$ are moduli of plastic anisotropy variable with the position of the considered point.

Although the preceding conditions based on equation of the general limiting surface, on strain-energy principles or on plastic potential respectively, have certain advantages in being more general, they are, for the study of the slip lines and of slip surfaces, less appropriate than the slip condition based on the limiting Mohr envelopes which is directly related to the directions of slip. Further, the previous theories may lead, in some cases, to the systems of equations of limit equilibrium of elliptical type which have not the real characteristics representing the slip lines and those cannot be determined.

2. THE PLANE PROBLEM OF PLASTICITY AND OF LIMIT EQUILIBRIUM

The basis for the analysis of plastic flow characterized by the rise of slip lines and slip surfaces is represented by the hypothesis of a rigid-plastic material, the relatively small elastic deformation being neglected.

If the boundary conditions are given in stress components, the plane-strain state of continuous media is defined by the differential equations of equilibrium

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} = X, \qquad \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y} = Y \qquad [9]$$

and by the limiting-state condition or condition of plasticity, which is represented by the limiting Mohr envelope and mathematically may be expressed by the relation between the maximal shear stress and the mean normal stress as follows

$$\tau_0 = F\left(\frac{\sigma_x + \sigma_y}{2}\right), \qquad [10]$$

i.e. for ideally plastic materials

$$(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2 = 4\tau_T^2 \qquad [11]$$

and for cohesive-loose materials

$$(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2 = (\sigma_x + \sigma_y + 2\sigma_c)^2 \sin^2\varphi. \qquad [12]$$

The plane problem as defined by the three above equations with three stress components σ_x, σ_y, τ_{xy} is statically determinate.

The analysis of the plane limiting state may be performed in four different ways.

On expressing from the limiting-state condition the stress components by means of two new variables representing the equivalent mean stress $\sigma = \frac{\sigma_x + \sigma_y}{2} + \sigma_c$ and the angle α of the larger principal stress with the positive direction of x-axis as follows for cohesive-loose materials

$$\sigma_{x,y} = \sigma(1 \pm \sin\varphi \cos 2\alpha) - \sigma_c, \qquad [13]$$

$$\tau_{xy} = \sigma \sin\varphi \sin 2\alpha \qquad [14]$$

and on introducing them into the differential equations of equilibrium, the following system of two quasilinear differential equations of limit equilibrium has been obtained

$$\frac{\partial \sigma}{\partial x} + \frac{\partial \sigma}{\partial y}\operatorname{tg}(\alpha + \nu) + 2\sigma\operatorname{tg}\varphi\left[\frac{\partial \alpha}{\partial x} + \frac{\partial \alpha}{\partial y}\operatorname{tg}(\alpha + \nu)\right] = A, \qquad [15]$$

$$\frac{\partial \sigma}{\partial x} + \frac{\partial \sigma}{\partial y}\operatorname{tg}(\alpha - \nu) - 2\sigma\operatorname{tg}\varphi\left[\frac{\partial \alpha}{\partial x} + \frac{\partial \alpha}{\partial y}\operatorname{tg}(\alpha - \nu)\right] = B, \qquad [16]$$

where $\nu = \frac{\pi}{4} - \frac{\varphi}{2}$ and A, B are functions of X, Y, φ, α.

For ideally plastic materials with zero angle of internal friction φ, the equations of limit equilibrium have the following form

$$\frac{\partial \sigma}{\partial x} + \frac{\partial \sigma}{\partial y}\operatorname{tg}\left(\alpha + \frac{\pi}{4}\right) + 2\tau_T\left[\frac{\partial \alpha}{\partial x} + \frac{\partial \alpha}{\partial y}\operatorname{tg}\left(\alpha + \frac{\pi}{4}\right)\right] = C, \qquad [17]$$

$$\frac{\partial \sigma}{\partial x} + \frac{\partial \sigma}{\partial y}\operatorname{tg}\left(\alpha - \frac{\pi}{4}\right) - 2\tau_T\left[\frac{\partial \alpha}{\partial x} + \frac{\partial \alpha}{\partial y}\operatorname{tg}\left(\alpha - \frac{\pi}{4}\right)\right] = D. \qquad [18]$$

The relationships [13] and [14] are valid also in the case of materials with a general curvilinear limiting Mohr envelope but the values of φ and σ_c have a different physical meaning, being variable with σ and the equations of limit equilibrium have the following general form

$$a\left[\frac{\partial \sigma}{\partial x} + \frac{\partial \sigma}{\partial y}\operatorname{tg}(\alpha + \nu)\right] + 2\sigma\operatorname{tg}\varphi\left[\frac{\partial \alpha}{\partial x} + \frac{\partial \alpha}{\partial y}\operatorname{tg}(\alpha + \nu)\right] = M, \qquad [19]$$

$$a\left[\frac{\partial \sigma}{\partial x} + \frac{\partial \sigma}{\partial y}\operatorname{tg}(\alpha - \nu)\right] - 2\sigma\operatorname{tg}\varphi\left[\frac{\partial \alpha}{\partial x} + \frac{\partial \alpha}{\partial y}\operatorname{tg}(\alpha - \nu)\right] = N, \qquad [20]$$

where a is function of φ, σ and α.

The preceding equations of limit equilibrium are of hyperbolic type having two families of characteristics representing the slip lines. The equations thereof may be obtained after equating simultaneously the numerator and denominator in the expressions for partial derivatives to zero. Then the characteristics are given by

$$\frac{dy}{dx} = \operatorname{tg}(\alpha \pm \nu) \qquad [21]$$

and for the relations along themselves, the following equations may be obtained

$$\frac{d\sigma}{dx} + 2\sigma\operatorname{tg}\varphi\,\frac{d\alpha}{dx} = A, \qquad [22]$$

$$\frac{d\sigma}{dx} - 2\sigma \operatorname{tg}\varphi \frac{d\alpha}{dx} = B. \qquad [23]$$

If only the denominator approaches to zero, we get the line of discontinuity defined by the Eq. [21], which was studied by W. Prager (44, 45), Ph. G. Hodge (44), R. Hill (23), G. S. Shapiro (70) and V. V. Sokolovskii (58).

The differential equations of limit equilibrium for cohesive-loose materials were expressed in the curvilinear coordinates of characteristics by F. Kötter (69) and for ideally plastic materials by L. Prandtl (48) and others.

Some authors have introduced the stress functions Φ_1, Φ_2 and by means thereof the equations of limit equilibrium may be brought to the following canonical form

$$\frac{\partial \Phi_1}{\partial x} + \frac{\partial \Phi_1}{\partial y} \operatorname{tg}(\alpha + \nu) = K, \qquad [24]$$

$$\frac{\partial \Phi_2}{\partial x} + \frac{\partial \Phi_2}{\partial y} \operatorname{tg}(\alpha - \nu) = L. \qquad [25]$$

V. V. Sokolovskii (59), for example, made use of logarithmic functions.

Other functions have the exponential form and for nonhomogeneous materials the integral stress functions have been used (54, 55).

J. Mandel (31) has analyzed the limit equilibrium of general continuous media in expressing the stress components σ_x, σ_y and τ_{xy} by means of the stresses σ_n and τ_n acting along the slip lines.

L. A. Meshkova (32) has given the solution of some plane problems of limit equilibrium using the limiting Mohr envelope in the form of cycloid.

Another approach to the analysis of the statically determinate plane limit equilibrium, derived by Z. Sobotka (56, 57), consists in differentiating by x and y the limiting relationship for the maximal shear stress having, in the case of general orthotropic nonhomogeneous material, the following form

$$(\sigma_x - \sigma_y)^2 + 4\varkappa^2(\sigma_x, \sigma_y; x, y)\,\tau_{xy}^2 = \Psi(\sigma_x, \sigma_y; x, y), \qquad [26]$$

where $\varkappa$ is the function of the orthotropy which for an isotropic homogeneous material is equal to 1. After eliminating the derivatives of the shear-stress component, the following equations of limit equilibrium in terms of stress components may be obtained

$$\lambda \frac{\partial \sigma_x}{\partial x} - \eta \frac{\partial \sigma_y}{\partial x} - 4\varkappa^2 \tau_{xy} \frac{\partial \sigma_y}{\partial y} = A, \qquad [27]$$

$$-4\varkappa^2 \tau_{xy} \frac{\partial \sigma_x}{\partial x} + \lambda \frac{\partial \sigma_x}{\partial y} - \eta \frac{\partial \sigma_y}{\partial y} = B, \qquad [28]$$

where λ, η, A and B are functions of σ_x, σ_y, τ_{xy}, Ψ and $\varkappa$. The characteristics of the preceding equations are given by

$$\frac{dy}{dx} = \frac{1}{\eta}\left(2\varkappa^2 \tau_{xy} \pm \sqrt{4\varkappa^4 \tau_{xy}^2 + \lambda\eta}\right) \qquad [29]$$

and the relations along themselves by

$$\xi_{1,2} \frac{d\sigma_x}{dx} - \eta \frac{d\sigma_x}{dx} = A\eta - B\xi_{1,2}, \qquad [30]$$

where

$$\xi_{1,2} = 2\varkappa^2 \tau_{xy} \mp \sqrt{4\varkappa^4 \tau_{xy}^2 + \lambda\eta}. \qquad [31]$$

The characteristics represent again the slip lines and coincide with the characteristics determined by the first method.

The fourth approach to the analysis of limit equilibrium was derived by A. Nadai (38, 39) who has obtained the following partial differential equation for the shearing stress

$$\frac{\partial^2 \tau_{xy}}{\partial x^2} - \frac{\partial^2 \tau_{xy}}{\partial y^2} = \pm 2 \frac{\partial^2}{\partial x \partial y}\sqrt{\tau_T^2 - \tau_{xy}^2}, \qquad [32]$$

valid for ideally plastic materials.

The equations of limit equilibrium and of slip lines in nonhomogeneous materials have been derived by Z. Sobotka (55) and C. Szymański (62). R. Hill (23) has developed the analysis of plane limiting state of strain in anisotropic metals and V. O. Geogdzhaev (15) has presented some special solutions for orthotropic bodies. For the geometrical properties of slip lines in the ideally plastic materials, three theorems of Hencky are valid (22, 11).

Hencky's first theorem states that the pairs of tangents to two slip lines of one and the same system at the points of intersection with a line of the other system are inclined to each other at the constant angle. According to Hencky's second theorem, the mean stress increases or decreases along a slip line apart from a constant proportionality with the angle which the tangent to slip line makes with a fixed direction as the point of tangency is advanced along it. Hencky's third theorem states that the radius of curvature R_β (R_α) of the α-family (β-family) of slip lines at the point of intersection with a certain β-line (α-line) increases or decreases by the length of arcs measured on the β-line (α-line). Then

$$\frac{\partial^2 R_\alpha}{\partial \alpha \partial \beta} + R_\alpha = 0, \quad \frac{\partial^2 R_\beta}{\partial \alpha \partial \beta} + R_\beta = 0. \qquad [33]$$

The analogy of the preceding equations with the telegraphic equation was noted first by C. Carathéodory and E. Schmidt (4). Other theorems relating the geometry of slip lines in plastic material have been presented by A. Nadai (39). J. Mandel (31) has developed the general theory of geometrical properties of slip lines in the materials with the general form of the curvilinear limiting Mohr envelope.

The determination of the direction of slip lines at any point in granular media with constant angle of internal friction may be performed graphically by means of three characteristic circles of Golushkevich (17) with radii following the proportion

$$r_1 : r_2 : r_3 = 1 : \frac{1}{\sin\varphi} : \frac{1}{\sin^2\varphi}. \qquad [34]$$

For the detailed theory of geometrical properties of slip lines see also ref. (54).

In general case, the numerical solution of the differential equations of limit equilibrium may always be easily performed using the method of characteristics and finite differences. The solution in finite differences is particularly appropriate for the limiting-state equations even in the case of a discontinuous nonhomogeneity of the material. It consists of determining the points of intersection of slip lines and in computing the stresses therein from the recursive formulas obtained after replacing the differentials in the equations of characteristics and in the relationships along the characteristics by finite differences. An extensive treatment of those numerical procedures has been given by V. V. Sokolovskii (58, 59). (See also refs. 23, 44, 45, 54 and 56.) V. G. Berezantsev (2) has developed the numerical procedures for axially symmetrical problems of limit equilibrium with slip surfaces in soils and Z. Sobotka (55, 56) has presented the treatment of numerical analysis of plane limiting states in nonhomogeneous materials.

The study of geometrical properties of slip lines has furnished some useful graphical solutions which may be very time-saving as reported by S. S. Golushkevich (17) and Z. Sobotka (54). The numerical and the graphical methods using the finite differences are based on characteristics representing the slip lines which may be mapped in four different planes (54). In some cases, the use of conformal mapping (54) may be suitable.

The exact solution of the equations of limit equilibrium may be performed, in some special cases, by Riemann's method (11, 23). The boundary conditions may also be approximately satisfied by the superposition of particular solutions. Some examples of this procedure have been given by H. Geiringer and W. Prager (11) who used series with trigonometric, exponential or Bessel functions respectively. An extensive treatment of the method, of the combination and of the geometrical meaning of particular solutions related to the slip lines in soils and other general continuous media has been presented by J. Mandel (31), who used, for some problems, the complex variable.

V. V. Sokolovskii (58) has applied the solution of the equations of plasticity in the form of Fourier trigonometric series obtained after a change of variables. By a similar reasoning W. Szczepiński (60) has derived the solution in the series of products of hyperbolic and exponential functions.

Another procedure makes use of Fourier integrals (11) starting from a system of particular solutions which can satisfy the given boundary conditions.

The slip-line theory was applied to a great extent for the solution of many important problems in soil mechanics such as determining the bearing capacity of foundations, the earth pressure on retaining walls, the limiting height and limiting contour of slopes, etc.

At the limiting state, generally three different slip zones develop (54, 55), namely the active zone under the loaded surface, the transient zone and the passive zone. Because the closed exact solutions as well the numerical procedures in finite differences are for the engineering practice in some cases involved and time-consuming, many authors have developed the approximate solutions of limit equilibrium of soils, treating the various slip zones as a whole or assuming certain simplified form of slip lines such as circular arcs, logarithmic spirals, etc. Such solution has been proposed for example by E. Beer (1), A. Caquot (3), J. Jáky (29), G. G. Meyerhoff (33), K. Terzaghi (64, 65), A. Myslivec (37), Z. Sobotka (54), and others.

Another approximate approach consists in seeking by means of analytical or graphical variational methods the unique principal slip line as an extremal line minimizing the coefficient of safety given by the ratio of active and passive forces. Such a procedure was applied especially for determining the stability of slopes, as has been shown by D. W. Taylor (63), K. Terzaghi (64, 65), A. Myslivec (37), M. N. Goldstein (16), Z. Sobotka (54), and others.

The solutions of technical problems using the slip-line theory related to forming and processing plastic metals are given by R. Hill (23), V. V. Sokolovskii (58), C. E. Pearson (47), T. K. Th. van Iterson (27), E. P. Unksov (68), A. D. Tomlenov (66), and others. A. Nadai (39) has described two orthogonal families of slip lines in the form of logarithmic spirals at the radial flow which takes place in thick-walled cylinder, around punched rivet holes and around the Brinell indentations while testing iron for hardness.

W. Szczepiński (60, 61) has presented the equations of plastic flow at stretch forming thin shells of double curvature.

3. THE COMPLETE ANALYSIS OF THE PLANE FLOW PROBLEM

If the boundary conditions contain also the cinematical variables, two further relationships must be considered, namely the condition of incompressibility

$$\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} = 0 \qquad [35]$$

and the relation connecting the stress and strain-rate components

$$\frac{2\tau_{xy}}{\sigma_x - \sigma_y} = \frac{\dfrac{\partial v_x}{\partial y} + \dfrac{\partial v_y}{\partial x} \pm 2\dfrac{\partial v_x}{\partial x}\operatorname{tg}\varphi}{2\dfrac{\partial v_x}{\partial x} \mp \left(\dfrac{\partial v_x}{\partial y} + \dfrac{\partial v_y}{\partial x}\right)\operatorname{tg}\varphi}, \qquad [36]$$

$$\dot{\varepsilon}_x = \frac{\partial v_x}{\partial x}, \quad \dot{\varepsilon}_y = \frac{\partial v_y}{\partial y}, \quad \dot{\gamma}_{xy} = \frac{\partial v_x}{\partial y} + \frac{\partial v_y}{\partial x}$$

being the strain-rate components and v_x, v_y the components of the velocity vector. The second Eq. [36] expresses the identity of the direction of the maximal shear-rate component or slip velocity respectively with the direction of slip lines. Eqs. [35] and [36] relating the strain-rate components represent with two differential equations of equilibrium and with the condition of plasticity or of limit equilibrium the set of five equations with five unknowns σ_x, σ_y, τ_{xy}, v_x and v_y. The system is hyperbolic having four families of characteristics, from which two families represent the slip lines and two other families the two orthogonal lines of maximum shear-strain rate, from which one coincides with one of the two slip lines.

In the case of the ideally plastic media, the angle φ of internal friction equals zero and the families of slip lines and the lines of maximum shear-strain rate coincide. If the boundary conditions are given in terms of stresses, the strain-rate components may be found after the solution of stress problem which is statically determinate.

The basic equations of the plane problem of limit equilibrium considering the strain-rate components were derived by Saint-Venant (51). The equations of flow velocities related to the slip lines

$$dv_1 - v_2\, d\alpha = 0 \qquad [37]$$

$$dv_2 + v_1\, d\alpha = 0 \qquad [38]$$

are due to H. Geiringer (10).

The numerical solutions in finite differences of the complete plane-flow problem using the method of characteristics were presented by R. Hill (23), W. Prager and Ph. G. Hodge (44) and by other authors. The analytical integrations by the method of particular solutions was given by H. Geiringer and W. Prager (11), whereas R. Hill (23) made use of the Riemann method.

The complete set of the equations for plane flow of loose and cohesive-loose media was presented by G. A. Geniev (13), who made use of numerical integration in finite differences.

Eqs. [35] and [36] with the equations of equilibrium define completely the plane plastic problem of strain provided that the strain rates are small. Otherwise, we have the case of steady plastic motion for which the equations of equilibrium must be replaced by the equations of steady motion of plastic mass.

4. THE NON-STEADY PLANE PLASTIC FLOW

In the case of the nonsteady flow, the equations of equilibrium are replaced by the equations of motion of a plastic mass as follows

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} = X + \rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y}\right), \qquad [39]$$

$$\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y} = Y + \rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y}\right) \qquad [40]$$

in the Eulerian form of the equations of hydronamics.

The other three equations of the basic set remain the same as in the case of steady plane flow.

The problem of nonsteady flow of ideally plastic mass with zero angle of internal friction was studied first by Saint-

Venant (51). M. I. Estrin (9) has presented some useful numerical solutions of special problems by the method of characteristics, using finite differences. G. A. Geniev (13) has derived the numerical solutions of nonsteady flow in loose and cohesive-loose materials with constant angle of internal friction.

5. AXIALLY SYMMETRICAL PROBLEMS

In the study of the axially symmetrical limit equilibrium three different trends may be observed

Some authors follow the Haar-von Kármán slip condition (18) which has made it possible to treat the axially symmetrical limit equilibrium as a statically determinate problem which may be resolved in quite an analogous manner as the plane plastic flow or plane limiting state.

According to the Haar-von Kármán hypothesis, the full limiting state in space is attained if two principal shear stresses are equal to the limiting value, i.e. if two limit Mohr circles are tangent to the limiting Mohr envelope. Then, the circumferential stress σ_θ equals at the limit equilibrium the minimal principal stress σ_3 if the deformation is directed toward the axis of symmetry and it equals the maximal principal stress σ_1 in the case of deformation in the opposite direction. In the case of ideally plastic material, it may be expressed by

$$\sigma_\theta = \sigma \mp \tau_T \qquad [41]$$

where $\sigma = \dfrac{\sigma_r + \sigma_z}{2}$ and τ_T is the shear stress at the yield limit, whereas for the cohesive and loose materials, we have

$$\sigma_\theta = \sigma(1 \mp \sin \varphi) - \sigma_c \qquad [42]$$

where $\sigma = \dfrac{\sigma_r + \sigma_z}{2} + \sigma_c$ is the equivalent mean stress.

The other stress components may be expressed in terms of the equivalent mean stress σ and of the angle α between the maximal principal stress and the positive direction of the x-axis as follows for cohesive and loose materials.

$$\sigma_{r,z} = \sigma(1 \pm \sin \varphi \cos 2\alpha), \qquad [43]$$

$$\tau_{rz} = \sigma \sin \varphi \sin 2\alpha. \qquad [44]$$

Substituting the preceding expressions into the differential equations of equilibrium leads to the following set of two quasi-linear differential equations

$$\frac{\partial \sigma}{\partial r} + \frac{\partial \sigma}{\partial z} \operatorname{tg}(\alpha + \nu) + 2\sigma \operatorname{tg} \varphi \left[\frac{\partial \alpha}{\partial r} + \frac{\partial \alpha}{\partial z} \operatorname{tg}(\alpha + \nu)\right] = K, \qquad [45]$$

$$\frac{\partial \sigma}{\partial r} + \frac{\partial \sigma}{\partial z} \operatorname{tg}(\alpha - \nu) - 2\sigma \operatorname{tg} \varphi \left[\frac{\partial \alpha}{\partial r} + \frac{\partial \alpha}{\partial z} \operatorname{tg}(\alpha - \nu)\right] = L, \qquad [46]$$

which are of hyperbolic type having two families of real characteristics representing the slip lines.

The analysis may be performed in the meridian plane in quite an analogous manner as in the case of the plane problem.

H. Hencky (22) has resolved in this way the problem of forcing the rigid punch into the ideally plastic mass and V. G. Berezantsev (2) has developed the theory of the statically determinate stress field for the analysis of axially symmetrical limit equilibrium in homogeneous soils. For statically determinate axially symmetrical limit equilibrium of nonhomogeneous materials, see ref. (56 and 57).

Another approach (56, 57) to the analysis of axially symmetrical limit equilibrium according to Haar-von Kármán hypothesis consists in expressing all relationships in terms of stress components in quite a similar manner as in the case of the plane state. Differentiating the limit condition

$$(\sigma_r - \sigma_z)^2 + 4\tau_{rz}^2 = \Psi(\sigma_r, \sigma_z, \tau_{rz}; r, z) \qquad [47]$$

by r, z and eliminating the derivatives of shear-stress component τ_{rz} by means of equations of equilibrium leads to the following quasi-linear equations of limit equilibrium

$$\chi \frac{\partial \sigma_r}{\partial r} - \zeta \frac{\partial \sigma_z}{\partial r} - 4\tau_{rz} \frac{\partial \sigma_z}{\partial z} = C, \qquad [48]$$

$$-4\tau_{rz} \frac{\partial \sigma_r}{\partial z} + \chi \frac{\partial \sigma_r}{\partial z} - \zeta \frac{\partial \sigma_z}{\partial z} = D, \qquad [49]$$

where χ, ζ, C and D are functions of σ_r, σ_z, τ_{rz} and Ψ.

The preceding equations are of hyperbolic type having two families of real characteristics representing the slip lines.

The statically determinate axially symmetrical problems may be easily resolved by the method of characteristics in finite differences computing step by step the coordinates in the points of intersection of the slip-lines network and the values of stress components or of other variables respectively in those points, as is shown in the works (2, 56, and 57).

The complete solution of the axially symmetrical problem for ideally plastic materials, taking into account the strain rates, was presented by R. Hill (23). Taking the slip lines in the meridional plane for curvilinear coordinates, this author has obtained the set of differential equations analogous to the Hencky equations which are valid for the plane problem. For the strain-rate components, R. Hill (23) has derived the equations which are similar to those derived by H. Geiringer (10) for the plane plastic flow.

5. THREE-DIMENSIONAL PROBLEMS

In contradistinction to the plane or axially symmetrical problems, the limit equilibrium and plastic flow in space was studied only to a very limited extent. Assuming, in accordance with the Haar-von Kármán hypothesis, the equality of two principal stresses σ_1 and σ_2 or σ_2 and σ_3 respectively, Z. Sobotka (57) has derived the relationships for the components of the stress tensor at the limiting state in homogeneous and nonhomogeneous cohesive and loose materials as follows:

$$\sigma_x = \sigma(1 \mp \sin \varphi \sin 2\alpha_x) - \sigma_c \qquad [50]$$

$$\tau_{xy} = 2\sigma \sin \varphi \cos \alpha_x \cos \alpha_y, \quad \text{etc.}, \qquad [51]$$

where α_x, α_y, α_z are the angles of the minimal principal stress with the coordinate axis x, y, z and $\sigma = \dfrac{\sigma_1 + \sigma_3}{2} + \sigma_c$ is the equivalent mean stress, σ_1 being the maximal and σ_3 the minimal principal stress.

Starting from the limiting-state condition of the anisotropic ideally plastic homogeneous materials represented by the irregular prism of plasticity with the corners equally inclined with respect to the coordinate axis σ_1, σ_2 and σ_3, D. D. Ivlev (28) derives six other relationships for the stress components.

Introducing the relationships for the stress components at the limiting state into the three differential equations of equilibrium in space and eliminating the value of α_z by means of the relation

$$\cos^2 \alpha_x + \cos^2 \alpha_y + \cos^2 \alpha_z = 1 \qquad [52]$$

leads to the system of three quasi-linear differential equations of limit equilibrium which are of the following type

$$a_{1k} \frac{\partial \sigma}{\partial x} + a_{2k} \frac{\partial \sigma}{\partial y} + a_{3k} \frac{\partial \sigma}{\partial z} + b_{1k} \frac{\partial \alpha_x}{\partial x} + b_{2k} \frac{\partial \alpha_x}{\partial y} + b_{3k} \frac{\partial \alpha_x}{\partial z} + c_{1k} \frac{\partial \alpha_y}{\partial x} + c_{2k} \frac{\partial \alpha_y}{\partial y} + c_{3k} \frac{\partial \alpha_y}{\partial z} = A_k \qquad [53]$$

where $k = 1, 2, 3$ and the coefficients a_{ik}, b_{ik}, c_{ik} are functions of σ, α_x and α_y.

These equations are of hyperbolic type having three families of real characteristic surfaces which represent the slip surfaces.

The solution of the general limiting-state problem may be effected by determining the characteristic surfaces and using the method of finite differences. Then we obtain the recursive formulas for computing the coordinates x, y, z of the points of intersection of characteristic surfaces and the values of σ, α_x and α_y therein.

According to the mentioned assumptions based on the Haar-von Kármán hypothesis, the three-dimensional problems may be treated as statically determinate without taking the strain-rate components into account. Nevertheless the solution of the three-dimensional limit equilibrium is very complicated and has been performed only for some elementary problems.

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Analytical Methods in Applied Mechanics

(See Revs. 5190, 5191, 5192, 5193, 5196, 5201, 5202, 5205, 5206, 5211, 5262, 5263, 5266, 5270, 5273, 5294, 5327, 5401, 5469, 5490, 5503, 5508, 5529, 5584)

Computing Methods and Computers

(See also Revs. 5190, 5191, 5192, 5213, 5235, 5283, 5284, 5293, 5400, 5468, 5507, 5529, 5602, 5662, 5776)

5170. Fehlberg, E., Numerically stable interpolation formulas with favorable error propagation for first- and second-order differential equations, NASA TN D-599, 20 pp., Mar. 1961.

The accuracy of a general class of stable numerical quadrature formulas is investigated, and a simple approximate criterion of accuracy, valid for formulas that are strongly stable, is developed and used to select optimum formulas from a large class of candidates. The analysis is extended to the case of a single second-order differential equation. The results of test calculations, showing a substantial improvement in accuracy over conventional Adams formulas, are presented.

(This paper is to appear in *ZAMM*.)

R. E. Esch, USA

5171. Squire, W., Some applications of quadrature by differentiation, *J. Soc. Indust. Appl. Math.* 9, 1, 94–108, Mar. 1961.

A quadrature formula is one in which the value of a definite integral is expressed in terms of the values of the derivatives of the integrand at its lower and upper limits. Author considers one such formula of a class discussed by Lanczos and applies it to a number of problems. Among these are: (a) Representation of functions; (b) eigenvalue problems; (c) calculus of variation problems; and (d) numerical integration of ordinary differential equations. The quadrature formula discussed here has a wide range of utility and should prove useful not only in the types of problems listed above, but in other situations as well, e.g., integral equations.

E. J. Scott, USA

5172. Ellenberger, K. W., On programming the numerical solution of polynomial equations, *Communications ACM* 3, 12, 644–647, Dec. 1960.

Author presents numerical methods for computing the zeros of polynomials. The basic technique utilizes a combination of the well-known Newton-Raphson and Bairstow iterative methods. The numerical procedure starts with a scaling step consisting of division of the polynomial by the geometric mean of its coefficients. Next, a simple numerical decision rule is used to determine if the sequence of coefficients should be reversed to increase probability of convergence and minimize loss of precision in the subsequent iterative processes. Finally, the Bairstow and Newton-Raphson methods are applied simultaneously until one or the other yields an iterated root or pair of complex roots to the equivalent polynomial equation.

Reviewer believes these techniques have real merit from a computational-reliability point of view, for experience indicates that it is highly unlikely that both numerical processes will fail simultaneously.

R. B. Grant, USA

5173. Matyash, I., Methods of analog computer solution of linear differential equations with variable coefficients, *Automation and Remote Control* 20, 7, 813–821, Mar. 1960. (Translation of *Avtomatika i Telemekhanika USSR* 20, 7, 837–847, July 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Author's point is to avoid the use of analog differentiators, since no purely electrical device can exactly simulate the transfer function *TS* (Reviewer thinks practical compromises can be found).

Author's solution appears to consist of some elaborate feedback system but, despite a serious attempt to understand the mathematical developments of the paper, reviewer cannot tell how the proposed system works.

J. M. Loeb, France

Book—5174. Rogers, A. E., and Connolly, T. W., Analog computation in engineering design, New York, McGraw-Hill Book Co., Inc., 1960, x + 450 pp. $16.

This book stresses applications rather than electronic circuitry of analog computers. It is intended as a complete treatment within itself (to mid-1958), and may be used as a graduate level text or as a reference. For comprehension, the reader should be acquainted with the differential equations of physics and engineering, and with complex variable circuit theory. Text starts with introduction to principles, capabilities and limitations of electronic analog computers. Description and use of each computer element is given, together with graphical symbolism for interconnections. Linear and nonlinear analysis are next treated, in both time and frequency domains. Phase plane, adjoint computing and other transform techniques are explained, together with treatment of discontinuities and use of random noise. These are illustrated on a variety of classical problems. Text concludes with application of techniques to selected problems in chemical processing and process control; nuclear reactors; aircraft performance, control and stability; and mechanical and electrical design.

This reviewer can unreservedly recommend the text as a working tool for the computer laboratory. Its price probably reflects the care necessary in checking the text, the extensive bibliography, and the 275 illustrations; the latter are mostly interconnection diagrams. V. Salmon, USA

5175. Joss, E. J., and Ross, D. S., Conformal transformations by analogue computer, *Brit. J. Appl. Phys.* **12,** 4, 178–179, Apr. 1961.

This paper describes the use of an analog computer to generate certain conformal transformations of the circle, these being of use in the analysis of stress patterns in the neighborhood of holes of various shapes. The relationship between the form of transformation and the shape produced is also discussed.

From authors' summary

5176. Jury, S. H., Development of memory core (high speed memory analog computer), *Indust. Engng. Chem.* **53,** 3, 173–177, Mar. 1961.

5177. Szabo, I., Pneumatic analog system computer unit (in Hungarian), *Meres Es Automat.* **9,** 2, 57–61, 1961.

Analogies

(See also Revs. 5174, 5177, 5278, 5444, 5776)

5178. Richards, T. H., Analogy between the slow motion of a viscous fluid and the extension and flexure of plates: a geometric demonstration by means of Moire fringes, *Brit. J. Appl. Phys.* **11,** 6, 244–254, June 1960.

The analogies mentioned in the title are discussed and the application of the Moire technique of determining slopes of a deflected plate is made to obtain solutions of extensional and viscous flow problems. It is shown that reasonably accurate and practical results can be achieved by the analogy and indeed studies of these applications are, to the reviewer's knowledge, being extended by other workers.

The range of viscous flow problems treated in the paper is small (only one non-trivial problem being studied) but the application of the technique to the investigation of some lubrication problems could well prove of interest.

O. C. Zienkiewicz, USA

5179. Sherman, F. S., Shock-wave structure in binary mixtures of chemically inert perfect gases, *J. Fluid Mech.* **8,** 3, 465–480, July 1960.

Starting with expressions for viscous stress, heat flux and diffusion flux, a continuum theory for steady flow of a binary mixture of chemically inert perfect gases through a normal shock of arbitrary strength is formulated. For shocks of vanishing strength the author's result is compared with Dyakov [AMR **8**(1955), Rev. 3832] by constructing solution in series expansion using Grad's [AMR **6**(1953), Rev. 972] shock strength parameter. Comparison is excellent. Shocks of arbitrary strength are treated by a numerical integration analogous to that used in one-component, pure-gas problems. It should be noted that author's page reference to Dyakov article should be 283 rather than 728.

A dozen examples were computed involving the eight parameters shock strength, ratio of specific heats, ratio of bulk viscosity to shear viscosity, Prandtl number, Schmidt number, thermal diffusion factor, molecular mass ratio, and initial mixture concentration. Gas pairs used were argon^{40}-argon^{36}, argon-neon, argon-helium, and xenon-helium.

Discussion of results included questions pertaining to degree of success with which weak-shock theory may be extrapolated to arbitrary shock strength, and accuracy of Navier-Stokes approximation for mixtures of gases of very different molecular weights.

Reviewer found paper interesting, especially the results with regard to argon-helium mixtures showing the mean-velocity change of helium almost 50 per cent accomplished before the random velocity (temperature) of helium has been much influenced. Author and reviewer intuitively expect these two quantities to start changing at approximately the same time. This strange result has been attributed to the requirement that mixture components share same temperature even though their molecular mass ratio is far from unity. Author suggests several theoretical avenues of approach, based on previous work, out of this dilemma. Author also briefly mentions some early experimental work by Professor D. F. Hornig at Brown University (now at Princeton) but gives no reference nor any indication of what was found. A. Kovitz, USA

5180. Abramson, H. N., and Ransleben, G. E., Jr., Simulation of fuel sloshing characteristics in missile tanks by use of small models, *ARS J.* **30,** 7, 603–612, July 1960.

Small models are predicated on similitude theory relating scale factors and the familiar Reynolds, Froude and Euler members for the problem of fuel sloshing aboard accelerated missile tanks. Sloshing modes were suppressed by floating cans on the liquid surface and by truncated conical rings, both of perforated materials mounted in the tanks. Rigorous modelling was not possible because of surface tension forces, although their total contribution would be small compared to the inertial and viscous forces.

E. G. Fischer, USA

5181. Denton, M. J., and Lipson, S. G., Electrolytic tank for studying the flow of liquids through tubes of various cross sections, *J. Sci. Instrum.* **38,** 4, 150–152, Apr. 1961.

Analog methods of solving the Poisson equation in two dimensions are discussed briefly. The electrolytic tank equivalent must have a uniform current source density; an approximation to this is achieved by introducing equal currents through conductors spaced in a square lattice. As examples, the flow velocity distribution in a tube of rhombic cross section is shown, and the equivalent radii for rhombic tubes of various angles are found.

From authors' summary

5182. Bradwin, H. A., Electrolytic tank simulator plots fields automatically, *Control Engng.* **8,** 3, 161, 163, Mar. 1961.

5183. Basin, M. A., MacNeal, R. H., and Shields, J. H., Direct-analog method of analysis of the influence of aerodynamic heating on the static characteristics of thin wings, *J. Aero/Space Sci.* **26,** 3, 145–154, Mar. 1959.

5184. Chetaev, N. G., The problem of Klein, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **24,** 1, 27–39, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The problem of Klein is defined by author as the development of the analogy between optics and analytical mechanics. Chetaev demonstrates that for stable conservative system the invariance of the quadratic form of Poincaré variational equations leads to a restriction on the solution expressible as a matrix of the uni-modular transformation. It is then demonstrated that the group of uni-modular linear transformations of stable motion has a representation in the complete Lorentz group (the basic group of transformations in the theory of light). Author assumes light phenomena to be pure wave phenomena and neglects all corpuscular representations. This paper completes the analogy for conservative systems. An extension to more general systems still needs to be done. M. R. Bottaccini, USA

Kinematics, Rigid Dynamics and Oscillations

(See also Revs. 5184, 5216, 5217, 5225, 5233, 5658, 5712)

5185. Valcovici, V., New formulations on the fundamentals of mechanics (in French), *Arch. Rational Mech. Anal.* **5**, 3, 249–262, 1960.

Paper generalizes the variational methods of classical mechanics to widen scope of such principles as those of Hamilton and least action. Generalization is extended to case of constrained systems: by replacing the normal virtual displacements in such systems by "virtual variations" which also involve time, a unified treatment of holonomic and nonholonomic constraints becomes possible. Extension consists in replacing δx_i by $\Delta x_i = \delta x_i - \dot{x}_i \delta t$ in the variational process. K. H. Griffin, England

5186. Chetaev, N. G., On the stability of rough systems, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24**, 1, 23–26, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The late N. G. Chetaev (or the translator?) defines *rough systems* as nonlinear systems for which the problem of stability can be solved by simple approximate methods. Author establishes bounds wherein the stability of certain nonlinear systems can be determined by linear equations with constant coefficients. Estimates of the largest and smallest deviation of the disturbed variables are given. Results are mathematically interesting but seem too laborious for manual solution and of limited use in a machine computation. M. R. Bottaccini, USA

5187. Chetaev, N. G., On certain questions related to the problem of the stability of unsteady motion, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24**, 1, 5–22, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

An expository paper in which certain theorems of Lyapunov are again proved and expanded slightly to give some algorithims useful in finding the characteristic numbers. Author mistakes Lyapunov's stability theorem (compare this paper, p. 7, with Andronow and Chaikin, "Theory of oscillations," p. 199). Correct statement of the theorem would render the proof on pages 7 to 10 unnecessary. The algorithims are interesting but not particularly enlightening. The translation from Russian is very awkward and often difficult to follow. M. R. Bottaccini, USA

5188. Chetaev, N. G., Note on classical Hamiltonian theory, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24**, 1, 40–41, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

This paper appears to be either a lecture note or a fragment of a projected book by the author. The question of stability of mechanical holonomic systems is discussed and author concludes that small dissipative forces are the barriers which make negligible any deviations generated by nonlinear exciting forces. As stated by author, this result was due to Lord Kelvin.
M. R. Bottaccini, USA

5189. Chetaev, N. G., On certain constraints with friction, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24**, 1, 43–47, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

A theoretical discussion of the application of Lagrangian methods to mechanical systems constrained by linear frictional connectors. Result is the differential equation for constrained systems in the Lagrangian form with the assumption that the work done by the friction forces under a virtual space displacement is zero. An expression for the rate of energy dissipation is then obtained in terms of Lagrangian multipliers. M. R. Bottaccini, USA

5190. Moiseyev, N. D., Interpolation averaged variants of the canonical problem of celestial mechanics, *ARS J.* **31**, 3, 387–389 (Russian Suppl.), Mar. 1961.

Considering the differential equations of motion of a particle in a restricted three-body problem in Hamiltonian canonical form, author splits the six variables into two groups of three. Requiring that the points in one group are restricted to a certain plane determined by a least square linear fit, he then averages the Hamiltonian over a bounded region in this plane. This averaged Hamiltonian, when inserted in the canonical equations, results in simplified equations admitting immediate determination of two independent integrals which are linear in the unaveraged variables. Similar results are obtained by averaging over a segment of a fitted line producing one integral. The Hamiltonian may or may not depend on time, and the averaged Hamiltonian preserves this dependence or independence. M. L. Juncosa, USA

5191. Moiseyev, N. D., Complete averaging of canonical problem of celestial mechanics with several intermediate elements, *ARS J.* **31**, 3, 390–392 (Russian Suppl.), Mar. 1961.

See preceding review. Author extends method to system of a number of particles. Again the canonical variables are split into two groups. Averaging is done over subsets of variables in each of the two groups leaving a Hamiltonian which is a function of certain auxiliary relatively arbitrary variables, which are linear or more general functions of the original variables. Integration of the canonical equations with averaged Hamiltonians in special cases is discussed. M. L. Juncosa, USA

5192. Moiseyev, N. D., Averaged variants of a semirestricted planar problem of three bodies, *ARS J.* **31**, 3, 393–399 (Russian Suppl.), Mar. 1961.

See preceding two reviews. The semirestricted problem considered is the motion of two planets about a sun so massive that their action on it as well as their addition to the total system's mass is negligible. The equations are in Keplerian form and one integral is obtained as the integral of the areas. Averaging the two perturbing potentials over the two mean anomalies is then carried out reducing the problem of determining the integrals to quadratures.

Single averaging with respect to only one mean anomaly, improved single and double averaging over eccentric components of the anomalies and single averaging of the Delaunay anomaly are also done.

For rapid first-order estimations of orbits in three-body problems, these methods seem to have value, especially in the doubly averaged cases where the problems reduce to quadratures.
M. L. Juncosa, USA

5193. Suddath, J. H., A theoretical study of the angular motions of spinning bodies in space, NASA TR R-83, 29 pp., 1960.

Euler's dynamic equations are applied to spinning bodies in space, are appropriately linearized, and solved by Laplace transforms. Results for a specific body subjected to a rectangular pulse pitching moment using linearized approximation compares satisfactorily with computer solution of the nonlinear equations. A small variation in the duration of the moment causes large differences in behavior, particularly if change is equal to half period of transverse momentum oscillation. Effects of inertia distribution on maximum angular deflection are discussed. Artificial damping which results from an idealized proportional control system is shown to be more advantageous for pencil-like rather than disk-like configurations. E. T. Welmers, USA

5194. Sitnikov, K., The existence of oscillatory motions in the three-body problem, *Soviet Phys.-Doklady* **5**, 4, 647–650, Jan./Feb. 1961. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **133**, 2, 303–306, July 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

5195. Teleman, S., On the first problem of self-vibration of an elastic body (in English), *Acad. Republ. Pop. Romine, Rev. Math. Pures Appl.* **4**, 4, 665–684, 1959.

Using theory of operators in Hilbert space, author considers vibration of an isotropic, homogeneous, elastic body with fixed boundary. Method can be applied to other problems involving eigenfunctions for elliptic differential operators.

G. Power, England

5196. Wierzbicki, W., Dynamical interpretation of the Ritz-Timoshenko method (in English), *Arch. Mech. Stos.* **12**, 4, 523–529, 1960.

Referring to load-displacement curve for a linearly elastic system, author constructs proof of validity of variational method intimately related to law of virtual work.

J. E. Goldberg, USA

5197. Stephenson, R. R., and Gaylord, E. W., Natural frequency of the compound centrifugal pendulum, *Appl. Scient. Res.* (*A*) **10**, 3/4, 180–184, 1961.

The equations of motion governing the free vibrations of the compound centrifugal pendulum are stated, and the linearized solution is given. A comparison is then made between the exact (numerical) solution of the nonlinear equations of motion and the linearized solution. This comparison is in the form of the ratio of the natural frequencies and is presented graphically and tabularly.

From authors' summary

5198. Pavlov, V. A., Influence of nutational vibrations of a gyroscope on its systematic divergence from the given direction (in Russian), *Trudī Leningrad In-ta Aviats. Priborostr.* no. 19, 159–166, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 12959.

An investigation is made of a balanced gyroscope with three degrees of freedom in a Cardan suspension. The author, by formally applying to the system of equations for the motion the method of successive approximation, succeeds in finding a formula in the second approximation which expresses the systematic divergence of the gyroscope by the coordinate ψ. The angular velocity of this systematic divergence is expressed by the formula

$$\dot{\psi} = \frac{I_H + I_B x}{I_c} \frac{I\Omega}{2I_c n^2} \dot{\vartheta}_0^2 \sin \vartheta_0 \left(n = \frac{I\Omega \cos \vartheta_0}{\sqrt{I_B I_c}} \right)$$

The author refers to work done by Magnus [K. Magnus, *ZAMM* **35**, 23–24, 1955] and by Plymale and Goodstein [B. T. Plymale, R. Goodstein, *J. Appl. Mech.* **22**, 3, 365–366, 1955] in which an analogous problem was investigated but without bringing forward any detailed deductions.

V. N. Koshlyakov

Courtesy Referativnyi Zhurnal, USSR

5199. Klotter, K., and Cobb, P. R., On the use of nonsinusoidal approximating functions for nonlinear oscillation problems, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 579–583, Sept. 1960.

In the Ritz-Galerkin method, the approximating function is usually taken as a Fourier series. In this paper, an alternative polynomial function is considered. The two methods are compared for the case of free oscillations with one degree of freedom. A two-term (parabolic) approximation is much better than a one-term sinusoidal approximation.

A. W. Babister, Scotland

Book—5200. Bogolyubov, N. N., and Mitropol'skii, Yu. A., Asymptotic methods in the theory of nonlinear vibrations (in Russian), Moscow, Fizmatgiz, 1958, 408 pp. + illus. 17 r 55 k; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13044.

In Chapter I natural vibrations are examined in systems close to the linear

$$\frac{d^2x}{dt^2} + \omega^2 x = \varepsilon f\left(x, \frac{dx}{dt}\right)$$

The solution is sought in the form of a resolution

$$x = a \cos \psi + \varepsilon u_1(a, \psi) + \varepsilon^2 u_2(a, \psi) + \dots$$

where $u_n(a, \psi)$ are the periodic functions of the phase angle ψ with a period of 2π. The magnitudes a and ψ are determined from the equations.

$$\frac{da}{dt} = \varepsilon A_1(a) + \varepsilon^2 A_2(a) + \dots$$

$$\frac{d\psi}{dt} = \omega + \varepsilon B_1(a) + \varepsilon^2 B_2(a) + \dots$$

A problem is set for the derivation of asymptotic approximations with not a large number of terms for the resolutions. Questions regarding the convergence of the resolutions are not investigated. In order to obtain a well-defined solution a condition is imposed on the functions $u_n(a, \psi)$ that these functions should not contain the first harmonics for the angle ψ. Formulas are derived for the first two approximations. It is shown that the equations for the first approximation for the case of steady vibrations coincide with the equations found by the Van der Pol method. An examination is made, as a particular case, of conservative systems close to the linear. A calculation is made for the vibrations of a mathematical pendulum without friction and with friction in two approximations and a comparison is given with the precise solution. The vibrations are also investigated of a system with a regenerated force in the form $p(x) = \alpha x + \gamma x^3$.

Method for the construction of stationary vibrations is described; this method opens up the possibility of obtaining higher quality approximations both for conservative as well as for unconservative systems. Three approximations are worked out for Duffing's problem in a quasilinear setting. A method is developed of equivalent linearization which resulted in obtaining equations for the first approximation. Methods are also described for finding the equivalent coefficient for damping and elasticity, based on the principle of energetic balance or on the principle of harmonic balance. The method is illustrated by means of examples of vibrations of a load with a nonlinear regenerating force and of vibrations of an electronic generator. It is demonstrated how, with the aid of an improved method of equivalent linearization, it is possible to obtain equations for approximations higher than the first. A system is then examined where the parameters change slowly with time

$$\frac{d}{dt}\left[m(\tau)\frac{dx}{dt}\right] + k(\tau)x = \varepsilon f\left(\tau, x, \frac{dx}{dt}\right)$$

Here $m(\tau) > 0$, $k(\tau) > 0$, while $\tau = \varepsilon t$ is slowness of the time. The solution is sought in the previous form, but functions $U_n A_n$ and B_n will, in addition, be also dependent on τ. Equations are obtained for the first two approximations both by means of the ordinary method and by the method using the equations for harmonic balance.

In chapter II questions are taken up dealing with the trajectories on the phase plane and special points. A classification is given of the special points of the first order and the characteristics for their stability for the system

$$\frac{dx}{dt} = P(x, y), \qquad \frac{dy}{dt} = Q(x, y)$$

Some concepts are advanced regarding boundary cycles. Poincaré's indices are the subject of exposition. Formulations of theorems on the existence and the uniqueness of boundary cycles are put forward and also the proof for one of these theorems with some simplifying assumptions. Lienar's graphical method is explained for the construction of integral curves on the phasal plane for some forms of the equations. Investigations are made on the relaxational vibrating systems on the examples of Van der Pol's equations with large values for the parameter ε, and also on the

vibrations of an electronic lamp working in a dynatron field. An exposition is furnished of the severe asymptotic method developed by A. A. Dorodnitsyn for the solution of the Van der Pol equations.

Chapter III deals with examinations of systems which are subjected to external periodic forces, clearly dependent on time

$$\frac{d^2x}{dt^2} + \omega^2 x = \varepsilon f\left(\nu t, x, \frac{dx}{dt}\right)$$

The conditions which might give rise to resonance are analyzed and a classification of different cases of resonance is given. Equations are obtained for the first two approximations for a non-resonance case. A special case is investigated in which natural vibrations are not present, the so-called "heteroperiodic regime." As an example, a Van der Pol equation is examined in which the right-hand side is equal to $E \sin \nu t$.

In chapter IV investigations are carried out on single frequency vibrations in nonlinear systems with many degrees of freedom. To start with the investigation deals with the free vibrations of a system in the form

$$\frac{dx_k}{dt} - \sum_{q=1}^{n} c_{kq} x_q = \varepsilon f(x_1, \ldots, x_n, \varepsilon) \qquad (k = 1, \ldots, n)$$

It is assumed that in the undisturbed system: (a) it is possible to have non-damping vibrations with some frequency such as ω, depending on two parameters; (b) that there is a unique static solution for $x_k = 0$; (c) that non-damping vibrations with frequencies a multiple of ω are impossible. Equations are derived for the first two approximations. The formal method is indicated which enables the same results to be obtained by using the principle of harmonic balance. Equations are derived analogously for the first two approximations for a system of differential equations of the second order. An energetic interpretation is given to the first approximation. A special case is looked into regarding steady single frequency vibrations with constant amplitude. This is followed by an investigation of a non-resonance as well as a case of principal resonance in a system with external periodic forces capable of being described by equations of the second order. A separate investigation is conducted for the special cases of a sinusoidal force and of a steady regime of vibrations in a system of a general type.

Chapter V is given up to an exposition of the averaging method for equations in the standard form

$$\frac{dx_k}{dt} = \varepsilon X_k(t, x_1, \ldots, x_n) \qquad (k = 1, \ldots, n)$$

Two first approximations are derived and the stability is examined in the first approximation. A method is shown for constructing more advanced approximations. As an example, the motion of a pendulum with a precise suspension vibrating in the vertical plane is examined. The averaging method is applied to the case of a rapidly rotating phase

$$\frac{dx_k}{dt} = X_k(\alpha, x_1, \ldots, x_r) \qquad (k = 1, 2, \ldots, r)$$

$$\frac{d\alpha}{dt} = \lambda \omega(x_1, \ldots, x_r) + A(\alpha, x_1, \ldots, x_r)$$

where λ is the large parameter. The motion is observed of a charged particle in a magnetic field.

The bases of the asymptotic methods are dealt with in Chapter VI. The theorem is put forward which evaluates the error in the first approximation obtained by the averaging method, to cover the case of an interval of time which can be of any duration but finite for a sufficiently small parameter ε. For the case of an infinite interval of time the theorems are substantiated which establish the correlation between the precise and the approximate solutions over an infinite interval of time, one of which refers to the case where the equation for the first approximation has a quasistatic solution, while the second and third refer to the case of a periodic solution.

A. P. Proskuryakov

Courtesy Referativnyi Zhurnal, USSR

5201. Kulikov, N. K., On a method of investigating steady forced vibrations of nonlinear systems with one degree of freedom (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 1, 22–33, Jan./Feb. 1959.

Most methods of handling periodic solutions of nonlinear differential equations give simple harmonic motion as the first approximation to the periodic solution. In the present paper the author presents a technique which gives a more precise description of the oscillations for the equation $x'' + \nu x' + F(x) = M \sin pt$ [1]. It is particularly for low frequencies, p, that the simple harmonic approximation is inadequate, and the author believes his approximation to be superior.

The approximate relation between x and t for a periodic solution is obtained as

$$\frac{F(x)}{F'(x)} = \frac{M[(F'(x) - p^2)\sin pt - \nu p \cos pt]}{\nu^2 p^2 + (F'(x) - p^2)^2} \qquad [2]$$

From this there is obtained a formula relating the amplitude A of the forced oscillation to the frequency p.

$$p^4 - (2F'(A) - \nu^2)p^2 + \frac{F'(A)^2(F(A)^2 - M^2)}{F(A)^2} = 0. \qquad [3]$$

Using formulas [2] and [3], author obtains a description of the various types of oscillations that can occur. The results include all the standard phenomena associated with nonlinear systems, and are quite similar to the results that are well known for Duffing's equation.

Several examples are given, including a very extensive discussion of Duffing's equation

$$x'' + \nu x' + x + \alpha x^3 = M \sin pt. \qquad [4]$$

W. S. Loud, USA

5202. Kulikov, N. K., On the study of free vibrations of nonlinear systems with one and two degrees of freedom (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 2, 81–87, 1959.

Author describes a method of estimating the frequencies of the periodic solutions of the differential equation $x'' + F(x) = 0$ and similar fourth-order equations. The initial approximation to frequency for a solution with positive amplitude a is $\sqrt{F(a)/a} = p_1$ which is obviously correct if $F(x)$ is linear. When $F(x)$ is not symmetrical about $x = 0$, the first approximation is

$$2\left[\frac{a}{\sqrt{F(a)}} + \frac{b}{\sqrt{F(b)}}\right]^{-1}$$

where $b < 0$ is the negative amplitude. The motion is approximated by the equation $F(x) = F(a) \cos p_1 t$ in the symmetric case and by a similar formula in the nonsymmetric case. The paper includes several examples.

The principal feature of the author's method is that it gives an approximation to the motion which does not give harmonic motion in nonlinear cases. He does not show conclusively that his method gives a more accurate approximation.

W. S. Loud, USA

5203. Shteinberg, T. S., Use of the method of the small parameter when investigating the periodic motions of systems with friction present (in Russian), *Trudî Ural'skogo Politekhn. In-ta* no. 74, 197–204, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 12998.

Poincaré's method of the small parameter is generalized for finding the periodic vibrations of a system with one degree of freedom, described by the equations

$$\dot{x} = \varphi(x,y,\mu), \qquad \dot{y} = \psi(x,y,\mu) \qquad [1]$$

where μ is the small parameter, φ, ψ are the material analytical functions of μ and of the variables x,y for the values of x,y from the region D, except for the values determinable by the equation $y = f(x)$; in the many cases of $y = f(x)$ the functions φ and ψ can tolerate disruption of the first order by all the variables; $f(x)$ is well defined, continuous and analytical in a sufficiently small proximity to certain values. A simplified system corresponding to system [1] is examined

$$\dot{x} = \varphi(x,y,0), \qquad \dot{y} = \psi(x,y,0) \qquad [2]$$

By solutions of systems [1] and [2] are understood to be functions of time satisfying equations [1] or [2] everywhere in region D, where the right-hand sides of the equations are the analytical functions of their variables and are "sewn in" in continuous fashion with the plurality of $y = f(x)$. It is assumed that system [2] has one, if only one, periodic solution. Adequate conditions are established for the existence of a periodic solution for the basic system [1], converted with $\mu = 0$ into a periodic solution of the simplified system. The case is separately examined where the simplified system is shown to be linear. As an example the following equation is examined

$$\ddot{x} + 2n_i\dot{x} + k_i^2 x = M_i + \mu G_i(x,\dot{x})$$

Here the curve along which disruption occurs is the axis x.

Yu. A. Mitropol'skii
Courtesy Referativnyi Zhurnal, USSR

5204. Gaiduk, V. I., On nonlinear oscillations in a weak external field, a description by Lagrange's equations, *Soviet Phys.-Doklady* **5,** 4, 713–717, Jan./Feb. 1961. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **133,** 4, 760–763, Aug. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

Instrumentation and Automatic Control

(See also Revs. 5198, 5611, 5657)

5205. Ku, Y. H., Theory of nonlinear control, *J. Franklin Inst.* **271,** 2, 108–144, Feb. 1961.

Paper is a review of the recent advances in analytical methods for studying nonlinear control problems. Part I is an introduction discussing some of the well-known nonlinear differential equations arising in the study of several scientific areas. Attention is then directed to a brief discussion of feedback control, linear and nonlinear. Part II describes three stages in physical systems study as identified by the author. The first is idealization of actual systems as linear and the development of linear analysis. The second stage involves actual analysis of nonlinearities by such methods as perturbation, iteration, and phase-space. The third treats of performance improvement and the concept of nonlinear control synthesis.

Part III reviews a number of linearization techniques. The describing function method developed by Kochenburger, Klotter, and others and the techniques of quasi-linearization, equivalent linearization, and piecewise linearization are discussed. Part IV treats of the general nature of phase-space analysis. Application of simultaneous phase-plane equations to nonlinear control systems is considered.

Part V deals with new analytic techniques and transforms. Methods covered include a reversion method of Pipes based on an algebraic procedure used in reverting power series, a number series transform method and a complex convolution method. Part VI presents a discussion of certain new concepts and theorems. Stability theory and new stability criteria are considered. Sampled-data systems and systems with random inputs are also discussed.

Reviewer believes this paper to be an excellent starting point for an investigator wishing to obtain a quick survey of the state of the art. The bibliography is very good and will prove quite helpful to anyone wishing to pursue certain topics in depth.

R. B. Grant, USA

5206. Skachkov, B. N., Stability region of certain nonlinear control systems, *ARS J.* **31,** 1, 134–135 (Russian Suppl.), Jan. 1961.

The systems considered are governed by

$$\dot{\eta} + R\eta = N\xi$$
$$\dot{\xi} = f(\eta, \xi)$$

that is, velocity control of a first-order system, where R and N are constants and $R > 0$. The function $f(\eta, \xi)$ is any continuous function except that it must take on the sign of a linear combination $\sigma = P\eta - \xi$ of the state variables, i.e., $\sigma f(\eta, \xi) > 0$, and $f = 0$ when $\sigma = 0$. If $\sigma = 0$ is called the "switching line," the similarity to related control problems is more evident. In a previous work, the author has demonstrated that this system is stable as a whole if

$$R - |NP| > 0$$

In this work he proves that this is also a necessary condition for stability by showing that if it is not satisfied, one can always find $f(\eta, \xi)$ such that the system is unstable. For $P \geqslant 0$ it suffices to take $f(\eta, \xi) = b\sigma$, $b > 0$, because the Hurwitz criterion applied to this linear system is identical to the above inequality. For $P < 0$ the author finds a class of functions $f(\eta, \xi)$, bounded by two such linear functions, for which the system is unstable if the inequality is reversed. The proof is performed in the η, ξ phase plane and hinges on finding the required bounding values of b (f is between, larger, or smaller than these bounds, depending on the region). However, the author merely gives expressions for these bounds and demonstrates that they make all trajectories diverge from a cleverly constructed closed region. The reasoning behind this construction is of a type generally unfamiliar in control literature in the English language and deserves study.

H. E. Lindberg, USA

5207. Pfeiffer, A., Stability of feedback systems with nonlinear relations between input and output (in German), *ZAMM* **38,** 11/12, 472–479, Nov./Dec. 1958.

Author examines problem of designing a control system which is to develop an output y nonlinearly related to the input x by $y = f(x)$, e.g. $y = Cx^{1/2}$ or $y = \ln(x/C)$. The condition is established for which uniform stability (i.e. transient response characteristics independent of operating point) can be achieved. A method of determining the dynamic response to large changes of x is suggested; this involves the use of a fictitious input η such that $x = \phi(\eta)$, being the inverse of the relation $\eta = f(x)$. Finally a method of achieving a response of uniform stability for such a control system is indicated by the use of a device which is capable of computing $U = C\phi(y)\,([x/\phi(y)] - 1)/[d\phi/dy]$, or its equivalent, instead of the $U = x - y$ of a simple linear feedback control system.

G. D. S. MacLellan, Scotland

5208. Tabarovskii, A. M., On uniform asymptotic stability (in Russian), *Nauchn. Dokladi Vyssb. Shkoly. Masb. i Priborostr.* no. 1, 210–217, 1958; *Ref. Zb. Mekb.* no. 10, 1959, Rev. 11207.

A system of equations is examined

$$\frac{dx_i}{dt} = X_i(t, x_1, \ldots, x_n) \quad (i = 1, \ldots, n) \qquad [1]$$

where $X_i (i = 1, \ldots, n)$ are assumed to be continuously differentiating functions x_i and t with $-\infty < x_i < \infty$ and $t \geqslant t_0 \geqslant 0$. In addition, it is assumed that $X_i(t, 0, \ldots, 0) \equiv 0$. The zero solution $x_i = 0$ of system [1] is named the uniform asymptotic stability as a whole, if (1) it is stable according to the Lyapunov standard; (2) for two arbitrary numbers $R_1 > 0$ and $R_2 > 0$ there is a time $T(R_1, R_2)$ such that every solution of $x_i = x_i(t, x_1^0, \ldots, x_n^0)$ in system [1], the initial values for which lie in the region

$$x_1^2(t) + \ldots + x_n^2(t) \leqslant R_1 \qquad [2]$$

satisfy the inequality $x_1^2(t) + \ldots + x_n^2(t) < R_2$ at all values of $t \geqslant T$; (3) for an arbitrary $R_1 > 0$ there exists an $R = F(R_1)$ of such a nature that any solution whose initial values lie in the region [2] does not come out of the region $x_1^2(t) + \ldots + x_n^2(t) < R$ whatever the value of $t \geqslant t_0$. The function $v(t, x_1, \ldots, x_n)$ is deemed to be determined as positive and infinitely large in the whole region if there is in existence a determined positive and infinitely big function $\omega(x_1, \ldots, x_n)$ which is dependent only on the coordinates and satisfies all $-\infty < x_i < \infty$ of the inequality $v(t, x_1, \ldots, x_n) \geqslant \omega(x_1, \ldots, x_n)$ with $t \geqslant t_0$. The following result was obtained. The zero solution of system [1] is uniformly asymptotically stable as a whole when, and only when, there exists a function $v(t, x_1, \ldots, x_n)$, determined as positive, infinitely large in the whole region and possessing the property that for any two numbers $\varepsilon > 0$ and $B > 0$ it is possible to obtain such a $T(\varepsilon, B)$ that the inequality $v > B$ would be accomplished, with $x_1^2 + \ldots + x_n^2 \geqslant \varepsilon$ for all $t \geqslant T(\varepsilon)$ and $dv/dt \leqslant 0$ in the whole region. E. A. Barbashin

Courtesy Referativnyi Zhurnal, USSR

5209. Kadymov, Ya. B., and Listengarten, B. A., Application of Laplace's discrete conversion for the investigation of systems of automatic control with distributed parameters (in Azerb.), *Izv. Akad. Nauk AzerbSSR, Ser. Fiz.-Tekhn. i Khim. Nauk* no. 5, 109–117, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13036.

A system of electric driving gear and automatic control in which the plant has links with distributed parameters is the subject of investigation. The author finds, in a closed form, an expression for the transition function in the opened chain presented in a discrete form; this is effected by looking at the transmission function as the sum of an infinite series in steps of e^{-p}, then finding Laplace's discrete conversion and going over to the originals in the product of functions presented in this way. This expression can be used as the basis of investigations of a closed system in discrete points. I. V. Pyshkin

Courtesy Referativnyi Zhurnal, USSR

5210. Albert, G. E., Statistical methods in prediction, filtering, and detection problems, *J. Soc. Indust. Appl. Math.* **8,** 4, 640–653, Dec. 1960.

Author investigates the important problem of prediction, filtering and detection of the main value function of a stationary stochastic process which has a spectral density function $f(\lambda)$ that is the reciprocal of a polynomial. The problem investigated concerns a process $x(t) = s(t) + e(t)$ where $s(t)$ represents the signal and $e(t)$ the noise component. It is assumed that $s(t) = \sum_{k=1}^{m} a_m g_m(t)$ with $g_m(t)$ known functions and a_m unknown coefficients to be estimated from observation of $x(t)$ over a finite time interval. The noise $e(t)$ is assumed to be a wide sense stationary process, with spectral density function $f(\lambda)$. A method is developed to find best linear unbiased estimates for the a_m. Four important examples are treated. Next, author discusses estimation of the a_n by applying least-squares estimating. The results then obtained are applied to the same examples and both methods are compared.

J. W. Cohen, Holland

5211. Chang, S. S. L., Shannon's theory and feedback systems, *ASME Trans.* **82** D (*J. Basic Engng.*), 1, 46–50, Mar. 1960.

Shannon's information theory can be used as a guide for rating feedback control systems and selecting system components as well. The author presents the results from some investigations in applying feedback in communication systems and on the other hand in the use of the analysis of information flow in feedback systems. In particular, calculations of required information capacities of control systems from input characteristics and fidelity requirements are developed. A further substantial part of the study deals with the calculation of the required capacity of system components and the determination of information capacity of control components from transfer functions and limiting conditions, as for instance threshold levels.

To be used practically, the study needs further development. Valuable criteria for control systems and components may be developed. P. J. Profos, Switzerland

5212. Meyfarth, P. F., Bang-bang versus linear control of a second-order rate-type servomotor, *ASME Trans.* **82** D (*J. Basic Engng.*), 1, 66–72, Mar. 1960.

Author first investigates the self-excited (high-frequency, low-amplitude) oscillations of a special closed-loop control with the aid of the describing function method and exactly, and shows numerically on a special example that the results of both methods agree well; the expansion of the exact formula in a series would have shown an approximation of the fourth order. By replacing the bang-bang system characteristic by that of a quasilinear one with a large controller gain the analysis for small input signals is very much simplified because the differential equation is then reduced from the third to the first order. Step and frequency responses of a linear and of the bang-bang system to inputs of different amplitudes are compared by analog computation.

H. St. Stefaniak, Germany

5213. Ronan, H. R., Jr., Hydraulic switching circuits: Parts 1 and 2, *Mach. Design* **31,** 4, 140–145, Feb. 1959; **31,** 5, 108–115, Mar. 1959.

Author outlines the application of AND, OR, and NOT logic functions, as developed for computer and control circuit design, to the synthesis of hydraulic circuits. Since there is direct analogy between various types of hydraulic valves (normally open or closed, two-way, four-way, etc.) and corresponding electrical circuit switches, the methods are similar: (a) write logic equations for desired outputs, (b) simplify equations, and (c) select suitable components.

Simple examples of technique are given in Part I. Part II describes components and elements for several complex circuits, as solved by three-step process given above; memory elements, counting with memory elements, and symmetrical circuits are also discussed. R. L. Sutherland, USA

5214. Dmitriev, V. N., and Chernyshev, V. I., Graphicoanalytic method of computing steady-state speed of pneumatic drives, *Automation and Remote Control* **20,** 10, 1335–1341, June 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 10, 1366–1373, Oct. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Paper deals with a method for computing the steady-state motion of a piston-type pneumatic drive mechanism having constant load and specified travel between transient response periods. Two modes of air flow, designated "sub-sub" and "sub-super" are considered. The former is for subcritical flow through both intake

and discharge valve openings, and the latter is for subcritical flow through the intake valve opening and supercritical flow through the discharge valve opening. It is shown that conditions of "super-sub" and "super-super" do not exist.

Making a number of simplifying assumptions, equations of the form $\dot{x} = k\phi_1 f$ are derived for the velocity of the piston, where x is the displacement of the piston, k a coefficient dependent on the absolute temperature and gas constant of the gas medium, f the effective area of cross section of valve openings, and ϕ_1 a function of supply pressure. Determining the region over which the equations are applicable, graphs are constructed showing relation between supply pressure and ϕ_1, with pressure drop across the piston as parameter. Experimental verification of the several assumptions made is carried out with an artificially established computed pressure in the cylinder space. It is shown that the maximum error does not exceed 7.6%.

B. M. Belgaumkar, India

5215. Kolesnichenko, S. G., On a tracking drive with gyroscopes on an oscillating platform, *Automation and Remote Control* **20,** 8, 1071–1078, Apr. 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 8, 1103–1110, Aug. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The problem of mounting a direction finder for automatically tracking heavenly bodies on nonstationary bases such as ships or airplanes is considered. In this presentation a gyroscope system is used to form a stable platform for mounting the direction finder with respect to the nonstationary base. It is found that oscillation of the gyrostabilized platform depends only on the Coulomb friction in the gyroscope's precession axis for oscillation of the base with respect to the horizontal axis, and that a drift of the gyro axis results from an oscillation of the base with respect to the vertical axis.

V. B. Haas, USA

5216. Gaignebet, E., and Lemoine, L., Angular vibration table (in French), *Rech. Aéro.* no. 77, 43–46, July/Aug. 1960.

The calibration of angular accelerometers and the evaluation of gyros require angular vibration tables.

A described mechanically driven table makes use of a cardan joint. The sinusoidal movement contains a few percent higher harmonics. Range: amplitude variable between 0 and 13°, frequency between 0 and 100 c/s, accelerations between 0 and 8500 rad/sec². Another solution is a freely rotating platform on which an eccentrically driven rotating mass moves in the plane of the platform.

Greater possibilities may be obtained with electromagnetic driven tables. A d c servomotor can be adapted for this purpose by applying a d c current through the field coils and an a c current through the rotor coils. The possibilities and electric requirements are discussed in some detail.

R. G. Boiten, Holland

5217. Korolev, A. I., The influence of asymmetry of the correction moments and the forces of friction in the suspension supports of a directional gyroscope on its precision (in Russian), *Trudī Leningrad In-ta Aviats. Priborostr.* no. 19, 18–23, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 11178.

An investigation is made of a directional gyroscope erected on a horizontal base which rotates relative to the vertical with an angular velocity of $\dot{\alpha}$. A correction device for the levelling of the angle θ, made up of the axis of natural rotation of the gyroscope with the platform's plane, is provided. The influence is examined of the asymmetry of the moment of correction on the assumption of the hysteresis nature of the correction, and also the influence of the asymmetry of the moments of friction on the supports of the suspension. Relevant calculation formulas are put forward which show that the asymmetry of moments of correction and friction result in the appearance of auxiliary divergences of the gyroscope into azimuth. Some experimental data are furnished.

V. N. Koshlyakov

Courtesy Referativnyi Zhurnal, USSR

5218. Afon'kin, I. V., and Koptyaev, P. P., Errors of gyroscopic tachometers (in Russian), *Nauchno-Tekhn. Inform. Byul. Leningrad Politekhn. In-ta* no. 12, 88–95, 1957; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 11180.

Some errors occurring in the use of double gyroscopic and single gyroscopic tachometers for measuring the angular velocity of the rolling of a ship when it is pitching and rolling as well are examined. As the result of the investigation of the equations of motion of a double gyroscopic tachometer obtained for small angles of declination of the axes of rotation of the gyroscopes and for small external angular velocities for the pitching and tossing, conditions were found in which the error was reduced to a minimum. Solutions of the equations were given, obtained by ordinary methods, which described the natural oscillations of a tachometer when friction on the axes of the casings of both the gyroscopes was operating, and also the forced oscillations for cases of constant periodic angular velocity of the rolling and of the velocity of the assigned function of time or arbitrary form. It was shown that a single gyroscopic tachometer, the equation for the motion of which was obtained from the equation for the double gyroscopic tachometer, reacts not only on the measured angular velocity of the rolling but on the angular rate of the rolling as well. Authors conclude that the double gyroscopic tachometer possesses advantages over the single gyroscopic instrument. They do so after solving an equation of the Mathieu type by the method of resolution by the small parameter for the case given above and by comparing the corresponding particular solutions of the equations of motion for single gyroscopic and double gyroscopic tachometers.

N. V. Gerasimov

Courtesy Referativnyi Zhurnal, USSR

5219. Danilin, V. P., A new method for reducing the error in gyrohorizons when a plane is banking (in Russian), *Nauchn. Dokladī Vyssh. Shkoly. Mash. i Priborostr.* no. 1, 189–192, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 12960.

An investigation is made of the motion of a gyrohorizon when the plane is banking for the case where the moment device of the transverse correction is joined to the sensitive element of the longitudinal correction. This showed that the declination of the axis of the gyrohorizon from the vertical gets continuously smaller with time. The application of this method in the gyrohorizon with proportional correction has no advantages over the method of disconnecting the transverse correction during banking.

V. N. Drofa

Courtesy Referativnyi Zhurnal, USSR

5220. Smirnov, E. L., Utilization of a symmetrical vibrating gyroscope for the measurement of variable angular velocities (in Russian), *Ucb. Zap. Leningr. Vyssh. Inzh. Morsk. Ucb-shche* no. 11, 27–31, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13024.

The question is investigated regarding the possibility of using a symmetrical vibrating gyroscope for the measurement of small (of the order of from 0.001 to 0.1 sec^{-1}) angular velocities, altering in accordance with the harmonic principle (periods of 5 secs or more). The investigation is carried out on the basis of a linearized system of equations for the motion of the gyroscope. Some experimental data are given.

V. N. Drofa

Courtesy Referativnyi Zhurnal, USSR

Book—5221. LeGalley, D. P., edited by, Guidance, navigation, tracking, and space physics, Vol. 3 (Proceedings of the Fifth Symposium on Ballistic Missile and Space Technology, Los

Angeles, August, 1960), New York, Academic Press, 1960, x + 450 pp. $9. (Revs. 5221-5232)

5222. Battin, R. H., A comparison of fixed and variable time of arrival navigation for interplanetary flight, 3-31.

5223. Sauer, C. G., Jr., Interplanetary injection guidance, 55-71.

5224. Spies, O. R., The problem of satellite navigation by use of a Doppler receiver, 73-101.

5225. Penzo, P. A., Analytical perturbation expressions for the restricted three-body problem, 203-229.

5226. Wolfe, R. R., and Arrow, B., Gravitational librations of a satellite and the influence on control systems design, 231-258.

5227. Brenner, J. L., The motion of an equatorial satellite of an oblate planet, 259-289.

5228. Merrilees, D. S., and Walker, J. C., Interplanetary trajectory simulation, 291-315.

5229. Beckner, F. L., Regions accessible to a ballistic weapon, 317-363.

5230. Raab, B., Plasma probes for space exploration, 367-392.

5231. Rubin, S., and Softky, S. D., Radio propagation experiments for investigating the solar wind, 393-403.

5232. King, Jean I. F., The dynamic stability of the upper atmosphere of Venus, 445-450.

End of Symposium

5233. Sabin, H. B., Seventeen ways to measure acceleration, *Control Engng.* **8,** 2, 106-109, Feb. 1961.

Elasticity

(See also Revs. 5261, 5262, 5274, 5275, 5279, 5280, 5292, 5294, 5306, 5317, 5329, 5354, 5366, 5398, 5727)

5234. Franchi, C. F., Elastic resistance of a hollow cylinder (in Italian), *Ingegnere* **34,** 7, 631-636, July 1960.

Experimental results are examined to see how the elastic limit of pressurized cylindrical containers correlates with maximum tension, maximum shear and maximum energy, and how these correlations are affected by composition of the material as indicated by varying Poisson's ratio. G. W. Housner, USA

5235. Seugling, W. R., An iteration method for the solution of finite deformation problems in elasticity (in English), *Arch. Mech. Stos.* **11,** 1, 3-15, 1959.

If a state of deformation of the given solid is assumed, the field equations of nonlinear elasticity permit determination of the corresponding state of stress and of the surface and body forces producing it. These forces are in general not those of the problem, and rates of force changes can be introduced to let the forces tend toward the given values. The partial differential equations governing the rates of displacement associated with these force rates are linear and their solution gives an improved estimate of the state of deformation. Once a sufficient approximation has been reached so that the space derivatives of the displacements are small, the final state of stress for finite deformations can be obtained by linear superposition, as it is in the infinitesimal theory when the displacements themselves are small.

Torsion of cylindrical bars is given as an example and compared with another solution in the case of circular cross section. Discussion is very general and theoretical throughout; particularisation will be awaited with interest. Practical application, which after all is the end and justification of such methods, still requires very comprehensive acquaintance with many known rigorous methods of solution of finite theory. M. L. Meyer, England

5236. Bolotin, V. V., The nonlinear theory of elasticity and stability viewed "as a whole" (in Russian), Rashetyi na Prochnost' no. 3; Moskva, Mashgiz, 1958, 310-354; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13849.

Paper begins with an examination of the linkage between the theory of stability viewed "as a whole" and the nonlinear theory of elasticity and the Poincare bifurcation theory. The problems are presented in a general form and the results obtained are difficult to review. In consequence the subsequent investigations were carried out on a model. An examination is made of a compressed hinge-fastened bar of constant section, which is situated on an elastic base. The resistance reaction from the base has the form

$$q = (\chi_0 + \alpha y + \beta y^2 + \gamma y^3 + \ldots) y$$

where y represents the transverse transpositions of the bar. In relation to the correlations between the coefficients $\alpha, \beta, \gamma, \chi_0$ there is a change in the form of the characteristics of the resistance and the different form is reflected in the curves characterizing the transition to new forms of equilibrium. A natural classification is furnished of the forms and characteristics of the transitions. V. I. Fedos'ev

Courtesy Referativnyi Zhurnal, USSR

5237. Berg, B. A., Regarding one form of elastic potential when the deformations are of large extent (in Russian), *Zap. Leningrad S.-Kh. In-ta* no. 73, 346-352, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13852.

The following hypothesis is adopted: The principal real stresses, multiplied by the coefficients of the deflection of the sections of the corresponding areas are equal to the stresses calculated on the basis of Hooke's generalized principle. The author derives the correlations for the quadratic theory of elasticity, indicates the corresponding form of potential of the adopted hypothesis and the correlations between the stresses and deformations in the arbitrary coordinates of the axes. Simplifications of these correlations are considered mainly in their application to different simple cases of deformation and the results are compared with the known deductions by Murnaghan [F. D. Murnaghan, *Amer. J. Math.* **59,** no. 2, 1937] and also of N. P. Zvolinskii and P. M. Riza [*Prikl. Mat. Mekh.* **2,** no. 4, 1938]. The physical bases for the determination of the constants is a question left untouched in the paper. L. A. Tolokonnikov

Courtesy Referativnyi Zhurnal, USSR

5238. Ju, F. D., On the Airy stress functions of plane dislocation problems, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 423-428, Sept. 1960.

Using the complex Airy stress function, author generalizes the application of the elastic-dislocation theory to a doubly connected region with an arbitrary dislocation cut. The solution is expressed in the linear combination of the multiple-valued and single-valued terms. The infinite plane with a circular hole and with a straight or logarithmic spiral cut is considered in detail. Author investigates the nature of the singularity at the terminus point of the cut and gives the proof of uniqueness of solution.

Z. Kaczkowski, Poland

5239. Hastrup, O. F., Solution of elasticity problems with the help of complex potentials (in Danish), *Bygnsstat. Medd.* **31**, 3, 93–110, Dec. 1960.

Author surveys conformal mapping method for plane stress problem, along lines of well-known treatise by Muskhelishvili, and applies method to infinite plane with triangular hole, square hole with internal pressure, and a cantilever plate with a hole. Photoelastic confirmation of results is presented.

C. E. Pearson, USA

5240. Dutt, S. B., On the stresses due to an overlapped circular hole on the neutral axis of a deep beam under constant bending moment, *Appl. Scient. Res. (A)* **9**, 6, 457–462, 1960.

By the use of bipolar coordinates the solution of the problem is obtained in an integral form. For the bending stresses a stress function of the form $1/6\ Ax^3$ is adopted, where x is the coordinate perpendicular to the neutral axis and $A = M/I$, I being the moment of inertia of the beam. Numerical values of the circumferential stresses have been calculated for some points of the hole.

C. A. Sciammarella, Argentina

5241. Youngdahl, C. K., and Sternberg, E., Transient thermal stresses in a circular cylinder, *ASME Trans.* **83** E (*J. Appl. Mech.*), 1, 25–34, Mar. 1961.

Author investigates the transient temperature distribution of an infinite circular elastic cylinder when a finite band of its surface between two cross sections is suddenly heated to a constant temperature and thereafter maintained at this temperature, the remainder of the surface being kept at zero temperature. Inertia effects being neglected the temperature distribution is determined independently by using Fourier and Laplace transforms. Associated fields of deformation and stress functions are deduced with the aid of Boussinesq-Papkovitch stress functions in definite integrals and infinite series form of which convergence is discussed.

Extensive numerical results are presented to show the temperature and stress variation along the axis and the surface of the shaft, improper integrals being evaluated on an IBM 650 computer.

D. N. Mitra, India

5242. Tuliszka, E., Temperatures and thermal stresses in disc rotors of thermal turbines under various working conditions (in Polish), *Arch. Budown Maszyn* **7**, 4, 387–477, 1960.

Temperature distribution in a steady-state flow through a turbine is considered with certain simplifying assumptions. A complete radial symmetry is taken and constant temperatures of stator disks are assumed. The resulting differential equations are solved approximately. From the temperatures obtained the distributions of thermal stresses in the rotors, taken as variable-thickness symmetrical disks, are computed. Finite differences appear to be the only possible technique of solution of the complex equations but certain limiting cases are studied analytically.

Author presents several worked examples indicating the serious magnitudes of thermal stresses and includes tables which should be useful for designers. The paper includes a comprehensive bibliography of the subject. O. C. Zienkiewicz, USA

5243. Ignaczak, J., The axially symmetric boundary-value problem of thermoelasticity for a hemispherical shell of any thickness (in English), *Arch. Mech. Stos.* **12**, 4, 415–435, 1960.

Title problem is solved theoretically, assuming that the shell is located in an axially symmetric temperature field. The paper is subdivided into four parts: (1) Statement of the problem; (2) Some auxiliary considerations: axially symmetric distribution of nuclei of thermoelastic strain in the elastic semi-space; (3) Temperature distribution in the shell. The reduction of the thermoelastic problem to the boundary-value problem of elasticity; (4) The solution of the residual problem. A general method for constructing sequences of solutions of the equations of the theory of elasticity in the region of a thick hemispherical shell, assuming axial symmetry.

From author's summary by E. H. Mansfield, England

5244. Bolotin, V. V., Equations for the non-stationary temperature fields in thin shells in the presence of sources of heat, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24**, 2, 515–519, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Neglecting the inverse thermoelastic effect, the temperature field under given distribution of sources of heat and conditions of heat exchange is first determined and the stress and deformation are then obtained. When the shell is thin the function T_0, the temperature of the mean surface and Θ the temperature gradient along the normal to the mean surface are determined independently from two differential equations obtained by using variational principle. Equations for temperature fields are however to be considered together with equations describing thermoelastic deformation in shells.

An inaccuracy in one equation describing the temperature field [see Melan and Parker, Termouprugie napriazheniia Stastionaruymi temperaturnymi poliami, Fizmatgiz, 1958] has been pointed out by the author. D. N. Mitra, India

5245. Parkus, H., Elastic thermal stresses in delta wings; Part 1, AFOSR TR 60-140 (Vienna Inst. Technol.), 52 pp. + figs., July 1960.

Basic differential equations in tensor form for shallow shells with constant thickness are derived in terms of shell deflections, temperature distribution and Airy's stress functions. These basic equations for conical shells are given in polar coordinates. Perturbation method for first approximation is applied in solving these equations and gives two fourth-order partial differential equations. The solution of these partial differential equations by means of finite difference, Fourier series expansion and Muskhelishvili's complex functions for biharmonic functions are shown and discussed. The use of electrolytic tank method to find the transformation function from an isosceles triangle to a unit circle is described and applied. T. H. Lin, USA

5246. Baron, H. G., and Bloomfield, B. S., Resistance to thermal stress fatigue of some steels, heat-resisting alloys, and cast irons, *J. Iron Steel Inst. Lond.* **197**, 3, 223–232, Mar. 1961.

5247. Jindra, F., Thermal stresses in the case of nonlinear elasticity relations (in German), *Ing.-Arch.* **28**, 109–116, Mar. 1959.

5248. Trostel, R., Stationary thermal stresses with temperature dependent thermal properties (in German), *Ing.-Arch.* **26**, 6, 416–434, Dec. 1958.

5249. Balas, J., and Hanuska, A., Symposium on the nonhomogenity in the elasticity and plasticity theory (in Czech), *Stavebnicky Casopis* **7**, 1, 7–32, 1959.

The stresses near the angular corners in thin elastic plates for various boundary conditions are determined. Combination of analytical (Fourier integrals) and experimental (photoelastic) methods is used.

The work represents a significant contribution to the knowledge of stress distribution in plane problems in elasticity.

R. M. Evan-Iwanowski, USA

5250. Franeck, H.-J., The inversion of the torsional stresses in a prismatic bar in general coordinates (in German), *Ing.-Arch.* **29**, 6, 428–435, 1960.

5251. Chobanyan, K. S., Torsion in a composite shaft of variable diameter (in Armenian), *Dokladf Akad. Nauk ArmSSR* **27**, 3, 139–144 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13894.

The problem is solved on the free torsion of a rod the section of which represents in itself a region bounded externally by a curvolinear square with a half-side of 1, and internally by a periphery with a radius of 0.9. The given two-bonded region is reflected approximately on a round ring. The radius of the outer region is equal to 1 and of the inner to 0.845. In this ring a determination is made of the function of a complex variable. The tangential stresses are calculated in the middle of the side and in the rounded top of the outer contour. Misprints occur in the paper.

Yu. A. Amenzade

Courtesy Referativnyi Zhurnal, USSR

5252. Babakova, O. I., Torsion of a bar of square section with a round hole (in Russian), *Trudî Khar'kovsk. Politekhn. In-ta* **14**, 53–58, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13899.

Author generalizes the common solution of the problem given in the title, which was worked out by Mitchell; this is accomplished by establishing complementary conditions which are essential for the determination of the stress functions during the torsion of a round shaft of variable section, made up of different materials soldered (welded) along the lateral surfaces. The contour conditions are found for the problem of torsion of the shaft when the shaft is covered with a layer of sufficiently small thickness.

Yi. M. Amenzade

Courtesy Referativnyi Zhurnal, USSR

5253. Boley, B. A., On a dynamical Saint Venant principle, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 74–78, Mar. 1960.

The accuracy of a quasi-static solution and of Saint-Venant's principle is studied for various rates of load application to a model of two Timoshenko beams connected by distributed springs. Good agreement is obtained with the more detailed quantitative analysis described previously [*J. Appl. Mech.* **22**, 204–206, 1955].

S. Kirkby, England

5254. Das, A. K., Note on twisting of an isotropic circular cylinder embedded in a resisting medium acted upon by couple at one end, the other end being fixed, *Indian J. Theor. Phys.* **7**, 3/4, 61–63, Sept./Dec. 1959.

The Michell theory of elastic torsion of bodies of revolution is adapted through its boundary condition to the constraint of a resisting medium which provides circumferential traction to the curved surface of the circular cylinder proportional to its torsional displacement. Series solution is of a well-known Fourier-Bessel type. Problem is torsional analog of beam on elastic foundation.

J. N. Goodier, USA

5255. Putvinskaya, E. I., The problem of the contact of an elastic hollow cylinder with an elastic plane (in Russian), *Trudî Kazansk. Aviats. In-ta* **43**, 61–76, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13850.

By assuming that the length of the portion of the elastic contact between the cylinder and the semiplane is very small by comparison with the radius of the cylinder R, and that the thickness of its wall $R-r$ is sufficiently small to enable calculations to be made for the transpositions by using the formulas for curved bar, it was found possible to derive an approximate integral equation for the problem on the elastic contact between the cylinder and the semiplane, the solution being effected by the numerical method. It is shown that a diminution in the rigidity of the cylinder, caused by the hollowness, results in an appreciable reduction in the contact stresses; however, in the case of thin-walled cylinders it is essential to take into account the stability of the wall to deflection.

N. A. Rostovtsev

Courtesy Referativnyi Zhurnal, USSR

Viscoelasticity

5256. Finnie, I., Steady-state creep of a thick-walled cylinder under combined axial load and internal pressure, *ASME Trans.* **82** D (*J. Basic Engng.*), 3, 689–694, Sept. 1960.

The axial load is not only due to internal pressure but other causes may contribute to this load, for example the own weight of the pressure vessel if in vertical position. The strain-stress relation of the material is $d\varepsilon/dt = C\sigma^n$, where ε is the octahedral shear strain and σ is the octahedral shear stress, whereas the components of the strain-rate deviator are proportional to those of the stress deviator.

The constant C and the exponent n may depend on temperature. All elastic strains are considered to be zero. Also in creeping there is no change in volume.

Numerical solutions for the stresses at the inner and outer diameter are given for different exponents n, different ratios of axial load: internal pressure and different ratios of inside-outside radius. Special attention is paid to the cases where the axial load is very large or very small. Interpolation procedures are discussed as well as an integration procedure to obtain the stress between inner and outer radius too.

J. P. Benthem, Holland

5257. Elias, E., Influence of secondary creep on a bent reinforced-concrete beam of rectangular cross section (in German), *Bauingenieur* **36**, 3, 93–96, Mar. 1961.

Paper derives equations for stress distribution in rectangular concrete beam reinforced by steel plate on convex surface, after given period of secondary creep. Restrictions of compressive stress only in concrete, Hookean behavior, and constant creep rate apply. Differential equation so developed is solved by numerical approximation for particular example to obtain distribution of compressive stress in concrete after finite amount of secondary creep.

Reviewer notes that problem can be completely solved using method of Lee [AMR **14** (1961), Rev. 2495] which applies Laplace transform to time-dependent stress-strain relations, so that the viscoelastic problem becomes an elastic problem in transformed variables. The associated elastic problem in this case has been solved at least in principle by several authors (e.g. Timoshenko, "Strength of materials," **1**, 221–224, 1955].

J. T. Bergen, USA

5258. Cottingham, W. S., Fluck, P. G., and Washa, G. W., Creep of prestressed concrete beams, *J. Amer. Concr. Inst.* **32**, 8, 929–936, Feb. 1961.

Author presents test results obtained during 7 years of sustained loading of prestressed concrete beam. The immediate elastic effect, the delayed elastic effect and the unelastic creep were measured. Although the tests were made on a limited number of samples (six beams), they show the characteristic behavior of prestressed beams.

This effect is mentioned in the creep graph of beams loaded to 1/2 design load. In the tensile zone they showed a slight initial tensile creep strain, but after 1 year loading period the strain is being reversed. This means the prestressing dominates the superimposed load in producing creep.

E. Ben-Zvi, Israel

5259. Nowacki, W., Thermal stress propagation in viscoelastic bodies: Part 1 (in English), *Bull. Acad. Polonaise Sci., Ser. Sci. Tech.* **7**, 4, 257–263, 1959.

An instantaneous heat source acts in an infinite body of linear viscoelastic material whose relaxation functions are independent of temperature and decrease exponentially with increasing time.

The particular integral represented by the thermoelastic potential is used as solution. Influence of deformation on temperature is neglected but dynamic terms are taken into account. The case of a periodically varying heat source is also considered.

H. Parkus, Austria

Plasticity

(See also Revs. 5249, 5256, 5262, 5297, 5305, 5337, 5342, 5347, 5350, 5381, 5782)

5260. Franciosi, V., On the criteria for the initiation of plastic flow—considerations and proposals (in Italian), *Ingegnere* **34**, 2, 103–110, Feb. 1960.

Among the criteria for the initiation of plastic flow for which theoretical formulations have been proposed by various authors the ones relying on the intrinsic curve (Mohr circle envelope) and based strongly on experimental evidence are nearest to reality.

In this paper the author gives a physical justification to the criteria of Hencky and Stussi on the basis of the theory of the intrinsic curve and proposes an energy equation which takes into account the shape of the curve itself.

Alternatively the author proposes a second equation which adopts as parameters for yielding the maximum strain differences.

F. Garofalo, USA

5261. Kloppel, K., and Yamada, M., Anisotropic flow conditions (in German), *Stahlbau* **29**, 6, 173–179, June 1960.

The elastic limit is defined in terms of a critical value for the distortional elastic strain energy of the orthotropic medium. Then the shape of the yield surface is determined by the nine constants of elasticity. It is shown that for a slight anisotropy of the medium this yield condition is equivalent to Hill's anisotropic yield condition.

J. F. Besseling, Holland

5262. Zaslavsky, A., A model for repeated residual deformation under repeated loading in same direction, *Bull. Res. Council Israel* **8** C, 2, 59–62, June 1960.

Author discusses analytically the development of residual stresses during repeated loading in the same direction. On the basis of his model, assuming an ideally elastic-plastic material, this is due to plastic collapse in the opposite direction during unloading if the collapse load is more than double the maximum elastic load (e.g. in triangular beams subjected to bending). The procedure is also applied to a horizontal beam (singly indeterminate) hinged on one end and supported in 2 positions, under a point load between the two supports.

V. Weiss, USA

5263. Safronchik, A. I., Unsteady flow of visco-plastic material in a circular tube, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **24**, 1, 200–207, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author investigates solution, for small times, of the equation (τ_0 is the yield stress in shear)

$$\rho v_t = \mu \nabla^2 v + r^{-1}\tau_0 - p_x(t)$$

for the axial velocity v and the radius $r_0(t)$ of the elastic kernel, subject to the initial condition $v(r,0) = F(r)\ \{r_0(0) < r < R\}$ and to appropriate boundary conditions at r_0 and R. By adopting a method of Kolodner for freezing problems, he obtains a functional equation for the determination of $r_0(t)$ in terms of which v may then be expressed.

G. Horvay, USA

Rods, Beams and Strings

(See also Revs. 5240, 5253, 5254, 5257, 5281, 5297, 5298, 5299, 5309, 5311, 5317, 5408, 5409)

5264. O'Donnell, W. J., The additional deflection of a cantilever due to the elasticity of the support, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 461–464, Sept. 1960.

Elastic distortion in the material adjacent to the supported end of a cantilever beam results in "fixed" end rotation that causes deflections additive to those due to stresses within the beam itself. Prior approximate analyses of support rotation are reviewed. The author presents a formula for mean rotation caused by a cubic stress distribution that the beam is assumed to apply at the support interface. Tests on model cantilever beams are presented and found to agree well with the author's formula. The relatively large effect of fillets between the beam and its support at the top and bottom boundaries is studied experimentally.

The models are small and the accurate measurement of the deflections required precise experimental techniques.

B. G. Johnston, USA

5265. Frisch-Fay, R., Non-linear bending of a cantilever under several concentrated loads, *Austral. J. Appl. Sci.* **11**, 2, 233–243, June 1960.

Author analyzes beams with large deflections without solving the basic nonlinear second-order differential equations. He utilizes the geometry of the elastic shape of the cantilever to solve the deflection problem under a number of parallel loads. The cantilever problem is solved by transforming it to an equivalent set of vertical strut problems with a vertical load applied at the free end of each strut. It is shown that the problem can also be solved for any number of inclined concentrated loads.

M. I. Yarmovych, USA

5266. Alwar, R. S., Solution of problems in beams on elastic foundations by the method of Laplace transformation, *J. Instn. Engrs., India* **40**, 12 (Part 1), 715–726, Aug. 1960.

After some introductory remarks including the Laplace transforms of the unit step function and impulse function, solutions of problems in beams both with transverse and axial loadings are given. It is shown, when the loading consists both of concentrated and uniformly distributed loads and moments, that in many cases the solution using the Laplace transformation is more convenient and economical than the classical one. A short list of Laplace transforms of functions occurring in problems in beams on elastic foundations is added.

V. Kopriva, Czechoslovakia

5267. Banerjee, K. K., and Basole, M. M., On analysis of beam and slab floors, *J. Technol., Calcutta* **4**, 2, 139–155, Dec. 1959.

Composite beam-and-slab structure discussed in this paper consists of a flat plate supported on a row of beams. Each beam together with the connected strip of the plate is considered as a unit. Various units are assumed first to be hinge-connected to each other, with the moments between units adjusted later. Results of analysis are in general agreement with experiments. Much better agreement between theory and experiment, however, is that obtained by P. B. Morice ["The analysis of right bridge decks subjected to abnormal loadings," Cement and Concrete Association, London, 1956].

Y.-Y. Yu, USA

5268. Kovar, A., The simple beam grill (in Slovakian), *Stavebnicky Casopis* **7**, 6, 340–353, 1959.

Three-way rectangular grid is studied by the deformation method. By proper rearrangements the obtained set of equations for twelve

redundant quantities is separated into four groups, each involving three unknowns only. Numerical example is worked out.

A. Sawczuk, Poland

5269. Unsac, O., An investigation for the determination of the cross-sectional dimensions of the prismatic bars in the case of uniaxial repeated loading (in English), *Bul. Istanbul Tekn. Univ.* **12,** 85–98, 1959.

Paper gives graphical method for optimal choice of cross section for bars subjected to fluctuating axial load, where fatigue limits are known.

C. E. Pearson, USA

5270. Kubitzki, H. H., Bending and torsion of asymmetrical box beams (in German), *Tech. Mitt. Krupp* **17,** 5, 207–229, Dec. 1959.

H. Ebner's method of analysis [NACA TM 744] for box beams with finite bulkhead spacing and warping constraints is extended to arbitrary box sections without corner flanges, with bulkheads rigid in their planes, with stringer forces transferred to the walls and with the usual assumptions about the wall stress distributions. The shear center is calculated for slender beams from the condition of minimum warping resistance, for short beams with the aid of redundant longitudinal force groups and the shear flow condition. The bending shear stresses then follow from the longitudinal bending stress distribution and the equilibrium conditions at the bulkhead edges. The warping constraint forces are calculated from redundant longitudinal force groups or, for symmetrical sections, from the corner displacements out of the planes of the bulkheads. The longitudinal bending stresses are also determined with the aid of redundant longitudinal force groups.

Examples are evaluated numerically in great detail, the calculations are elementary though lengthy, and designers will find this article a direct aid to the design of such structures.

M. L. Meyer, England

5271. Frisch-Fay, R., The deformation of elastic circular rings, *Austral. J. Appl. Sci.* **11,** 3, 329–340, Sept. 1960.

A straight, flexible strip is bent into the form of a circular ring and subjected to two equal and opposite radial forces. The discussion is restricted to deformations in the initial plane of the ring. The analysis shows that the elastic line of the deformed ring is always a segment of the nodal or of the undulating elastica. Coordinates corresponding to different values of the load are given and the method is explained by a numerical example.

From author's summary by H. D. Conway, USA

Plates, Shells and Membranes

(See also Revs. 5234, 5243, 5245, 5301, 5302, 5303, 5304, 5305, 5306, 5307, 5308, 5315, 5316, 5364, 5406, 5701, 5782)

5272. Sollazzo, A., An exact solution of quadratic plates with all edges built in (in Italian), *G. Gen. Civ.* **98,** 7/8, 559–568, July/Aug. 1960.

The problem of the rectangular, elastic, homogeneous and isotropic plane plate clamped along its boundary is usually reduced to the solution of an infinite system of linear algebraic equations. This paper gives a calculation method for such square plates in which the solution is expressed by a series development whose coefficients are obtained by a recurrence formula.

P. P. Teodorescu, Roumania

5273. Szmodits, K., Determination of limits in solutions of plate problems (in English), *Acta Techn. Acad. Sci. Hungaricae, Budapest* **29,** 3/4, 245–250, 1960.

Function-space theory is used to determine upper and lower bounds in certain types of thin plate problems for which exact solutions are not obtainable. Method is a development of work done by J. L. Synge.

D. M. A. Leggett, England

5274. Dhaliwal, R. S., Bending of a circular plate with a central hole by concentrated edge forces and couples, *Appl. Scient. Res. (A)* **9,** 6, 411–423, 1960.

Author considers three particular cases of loading of a circular thin plate with a concentric hole. The plate is subjected to either four point forces or two concentrated bending or twisting couples. Moments, shearing forces and deflections are calculated and given in the form of diagrams and numerical tables. The problem is solved by means of the complex variable method.

Z. Olesiak, Poland

5275. Rudiger, D., The Ritz and Trefftz processes in Reissner's theory of plates (in German), *Öst. Ing.-Arch.* **13,** 4, 257–263, 1960.

It is difficult to understand author's deduction of his new variational principle, an extension of the principle of minimum potential energy expressed in the displacements of the slab. All the prescribed boundary conditions for displacements and forces are natural conditions of this new variational principle and the displacements admitted to competition are not restricted by any boundary condition. Reviewer believes author's recent paper, "A new variational principle in elasticity" [*Ing.-Arch.* 1961, p. 221], shows more clearly the relation to the known principle of minimum potential energy. Any restriction can be removed by use of a Lagrange multiplier. Unfortunately author does not begin with this simple remark.

H. Schaefer, Germany

5276. Pirogof, I. M., Tension on a deflected plate weakened by a hole into which a rigid socket has been forced (in Russian), *Dop. Akad. Nauk URSR* no. 5, 512–514, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13876.

Using A. I. Lufe's methods ["Statics of thin-walled elastic shells," Moscow, Gostekhteorizdat, 1947], the stresses are determined in the vicinity of a rigid round socket forced into a hole of a cylindrical panel in tension along the generatrices. It is shown by means of a numerical example that the coefficient of the stress concentration becomes larger because of the panel curvature.

V. I. Feodos'ev

Courtesy Referativnyi Zhurnal, USSR

5277. Dulacska, E., Thin-shell construction of elliptical ground plan (in Hungarian), *Mélyépítéstudományi Szemle* **10,** 6, 284–286, June 1960.

The membrane stresses of hyperbolic and parabolic shells of elliptical ground plan are treated. The flexible edge beams, according to the author's assumption, take axial forces only. Another important assumption which simplifies the problem significantly is: if a curve in the space is the catenary line of all forces lying in the planes of tangency of the curve, then the projection of the space curve on the ground plan will also be a catenary line of the projected loads. Thus the three-dimensional problem has been reduced to a two-dimensional one.

R. Szilard, USA

5278. Monakhenko, D. V., and Proskuryakov, V. B., Scaling the state of stress of thin shallow shells (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 6, 161–163, Nov./Dec. 1960.

The similarity coefficients are given for modeling of thin shells, on the basis of Karman equations.

W. Urbanowski, Poland

5279. Akselʹrad, E. L., Deformation of shells subject to variation of temperature through the thickness (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 6, 158–160, Nov./Dec. 1960.

Author investigates a thin shell. The Young modulus, Poisson number and the coefficient of thermal expansion depend only on the coordinate along the normal to the shell. The shell is subjected to the action of a temperature field varying along the thickness. It is proved that the thermal deformation of the shell can be computed as the result of the action of the "thermal loading" composed of the following factors: (1) normal pressure acting on the surface of the shell, (2) stress normal to the edge, (3) bending moment applied on a part of the edge.

W. Urbanowski, Poland

5280. Naghdi, P. M., On Saint Venant's principle: Elastic shells and plates, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 417–422, Sept. 1960.

The validity of Saint-Venant's principle for elastic shells and plates is examined in a manner similar to that of E. Sternberg [*Quart. Appl. Math.* **11**, 393–402, 1954; AMR **7**(1954), Rev. 3147]. Author comes to following conclusions: "If the loads acting on the shell maintained in equilibrium are purely edge loads, then the orders of magnitude of the displacements and stresses are in accord with the traditional statement of Saint-Venant's principle. If the loads on the shell are purely surface loads, then the conclusions concerning the orders of magnitude of the displacements and stresses are the same as those of the modified principle."

Z. Kaczkowski, Poland

5281. Pshenichnov, G. I., Static analysis of lattice-type shallow cylindrical shells (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27**, 171–178, 1960.

Author analyzes a shell segment, consisting of a (square-meshed) network of interlocked curved beams oriented at 45° to the cylinder axis, subject to a distributed lateral load. He replaces the net by an equivalent isotropic shell and, in contrast to previous work [*Inzbener. Sbornik Akad. Nauk SSSR* **26**, 1958], takes full account of the beams' torsional stiffness and their bending stiffness in the tangent plane. Linear shallow-shell theory is used, expressed in terms of a displacement function, and a Fourier series solution is obtained for simple support boundary conditions. An example calculation of lateral deflection and bending moments is made for a tubular network subject to a uniform pressure. Results are shown for 2–, 3–, and 4–term series solutions. A difficult problem handled in routine, businesslike fashion.

R. W. Leonard, USA

5282. Dulacska, E., Shell structure shaped like a scallop-shell (in German), *Acta Techn. Acad. Sci. Hungaricae, Budapest* **29**, 3/4, 397–405, 1960.

The surface of a scallop-shell, like the catenary line of an arch, can be determined so that the governing internal forces are compressive forces acting in the direction of the shell's curvature (membrane condition). The author assumes in his derivation that the boundary condition is also free from moments. A typical scallop-shell with polygonal ground plan has been investigated. The reviewer feels that for larger structures these assumptions are not valid and the vertical deflection of the ribs with the moment effects must be considered.

R. Szilard, USA

5283. Soare, M., Application of the many-point method for the study of shells (in German), *Rev. Mécan. Appl.* **5**, 3, 417–436, 1960.

The "many-point method" of Collatz for obtaining numerical solutions of Poisson's equation is described and illustrated by a numerical example of an elliptic paraboloid shell with rectangular plan under a uniform load. Membrane shell theory is used, in which case stress resultants are known to be expressible in terms of second partial derivatives of a stress function satisfying Poisson's equation. Numerical results for the stress function agree well with the exact analytical solution of the problem. Numerical results for the stress-resultants will be less accurate and are not compared with the analytical solution.

It is not clear whether the method illustrated yields any more accurate results for the stress resultants than ordinary relaxation techniques.

R. A. Clark, USA

5284. Galletly, G. D., Bending of 2: 1 and 3: 1 open-crown ellipsoidal shells, Welding Res. Council Bull. 54, 9 pp., Oct. 1959.

Differential equations of equilibrium for constant thickness shells of revolution subjected to internal pressure and edge bending loads are solved on a high-speed digital computer.

Influence coefficients for the edge deformations of open-crown ellipsoidal shells are tabulated for various parameters of the crown opening, thickness, diameters, angles, etc. Paper is very useful for designers.

M. Hampl, Czechoslovakia

5285. Pirogov, I. M., Stress distribution near openings in a cylindrical shell under the action of concentrated loads (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 2, 146–147, 1959.

Author applies Lurʹe's solution [A. Lurʹe: "Statics of thin-walled elastic shells" (in Russian), Moscow, 1947, pp. 234–243] for the stress concentration around a circular opening of radius ρ_0 in a circular cylinder of radius a to the case of two concentrated forces acting along the diameter of the opening parallel to the cylinder's generatrix. The solution is valid for very small openings only with $\rho_0/a \ll (t/a)^{1/2}$, t denoting the thickness of the shell.

A numerical example shows that the membrane stresses are about 8% higher than in the plane case, and that the bending stresses are negligible.

A. Kornecki, Israel

5286. Rudis, M. A., On the analysis of symmetric deformations of conical and spherical shells of constant thickness (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 2, 147–150, 1959.

On the basis of the general equations of the theory of thin shells as presented by Novoshilov, author derives the solutions for conical and shallow spherical shells subjected to axially symmetric load in the form of Bessel functions of first and zero order respectively. An example illustrates the calculation of the complex constants of integration. The same problems solved on the basis of slightly different equations [W. Fluegge: "Stresses in shells," Springer, 1960, pp. 372 and 345] lead to Bessel functions of second and first order respectively.

A. Kornecki, Israel

5287. Konovalov, B. A., The calculation of conical shells on the basis of V. Z. Vlasov's variational method (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Aviats. Tekhn.* no. 4, 51–61, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13921.

An exposition is given of the derivation of equations for the calculation of faintly conical shells of constant thickness based on Lagrange's variational method. Stepped functions of the contour coordinate are adopted as functions approximating the transverse distribution of the flexures. Particular cases are investigated and it is found that for shells with a rigid contour the equations obtained represent a system of linear differential equations with variable coefficients of the Euler type.

A. N. Elpatʹevskii
Courtesy Referativnyi Zhurnal, USSR

5288. Borocz, I., Approximate determination of maximum moments in plates and shells under concentrated load (in Hungarian), *Mélyépítéstudományi Szemle* **10**, 10, 469–471, Oct. 1960.

The same simplified method developed in the paper is applicable for plates and for shells. It is based on the approximate determination of the maximum moment in a circular simply supported slab loaded by a circular uniformly distributed load at the center. The concentrated load is substituted by a load which is uniformly distributed on a limited surface. The application of the method is shown by numerical examples. R. Szilard, USA

5289. Lukash, P. A., and Leont'ev, N. N., Analysis of spherical shells, supported on a rigid foundation (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **25**, 154–163, 1959.

Author examines a spherical shell of raduis R partly filled by a fluid with overpressure, resting on a rigid foundation of concave spherical form of radius $R_1 > R$. It is assumed that in the region of contact the deflection of the shell is paraboloidal or sinusoidal. The radius of contact is calculated, as well as the distribution of pressures on the foundation, making use of the Vlasov equations for shallow shells. A numerical example is given. The bending moments arising in the region of contact seem to be small.

W. Urbanowski, Poland

5290. Raer, G. A., Calculations for the strength of the disks of the working wheels of centrifugal compressor machines (in Russian), *Energomasbinostroenie* no. 7, 10–14, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12570.

A. D. Kovalenko's solution [Plates and shells in the rotors of turbomachines, Kiev, Izd-vo Akad. Nauk URSR, 1955] is used when examining the stressed state in the disk of the wheel. It is shown that, in the majority of cases occurring in practice, when the relative rigidity of the covering disk is small, the transverse loads due to the blades can be disregarded, which simplifies the calculation diagrams for the stresses in the disk of the wheel with the experimental ones for cases of symmetrical and asymmetrical isolated disks and also when loading them with blades with a covering disk. The comparison confirms the possibility of disregarding, in the majority of cases, the action of moments and forces due to the blades on the disk, and shows the relation of the stresses on the boring of the disk to the dimensions of the hubs and the character of their union with the plane of the disc. The calculated stresses for a symmetrical disk and for a disk in the form of a conical shell agree satisfactorily with the experimental.

V. A. Vinogradov
Courtesy Referativnyi Zhurnal, USSR

5291. Aben, Kh. K., Stability and transcritical deformation of a long cylindrical panel during shear (in Russian), *Izv. Akad. Nauk EstSSR, Ser. Tekhn. i Fiz.-Matem. Nauk* **7**, 1, 3–6, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13951.

Investigations are carried out on the large deflections of an elongated slanting round cylindrical panel subjected to the action of shear forces along its edges. It is assumed that the long edges are hinge-supported, draw together freely and receive a relative longitudinal change of position which is constant by the length of the panel. Use is made of the variational formulas proposed by N. A. Alumyae [see in "Scientific and technical conference on the calculation of flexible plates and shells, Moscow, Izd-vo Voennovozd. Inzh. Akad., 1952]. The function for bending w and the stresses function in the median surface φ are approximated in the form

$$w = A \cos(m\alpha - n\beta) \cos q\beta + B(1 + \cos 2q\beta) + C \cos 2(m\alpha - n\beta)(1 + \cos 2q\beta)$$

$$\varphi = K \cos(m\alpha - n\beta) \cos q\beta + L \cos 2q\beta + M \cos 2(m\alpha - n\beta)(1 + \cos 2q\beta) + \tau t \alpha\beta$$

Here α, β are the coordinates along the generatrix and on the arc, tR and bR are the thickness and width of the panel, R is the radius of the curvature of the median surface, τ is the mean tangential stress along the edge. The upper critical load is determined and the transcritical deformation of the panel is investigated.

A. S. Vol'mir
Courtesy Referativnyi Zhurnal, USSR

5292. Galletly, G. D., Influence coefficients and pressure vessel analysis, *ASME Trans.* **82** B (*J. Engng. Industry*), 3, 259–269, Aug. 1960.

Edge displacements at a junction are written in terms of unknown forces, and displacement compatibility conditions are used to form simultaneous equations from which the forces are determined. Existing tables of influence coefficients for hemispheres, positive- and negative-curvature toroids, and open crown ellipsoids simplify the work without the need for specialized knowledge. Two detailed numerical examples are given: (1) a cylinder closed by a torispherical head and (2) a cylinder joined to a smaller cylinder by an ellipsoidal-toroidal shell. In Case 1, the maximum stress is more than twice that calculated from the simple ASME Code formula. Case 2 is not explicitly covered by the ASME Code but use of a standard formula for the ellipsoidal part yields a stress only 70% of theoretical value. Author has deposited extensive sets of interior influence coefficients for positive- and negative-curvature toroidal shells in following society libraries: ASME, ASCE, Instn. Mech. Engrs. (England).

Both designers and analysts will find paper lucid and helpful.

R. B. McCalley, Jr., USA

5293. Birkgan, A. Yu., and Vol'mir, A. S., Study of large deflections of rectangular plates with the aid of digital electronic computers (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 2, 100–106, 1959.

Large deflections of plates under distributed loads and with finite edge ratios are solved by the method of successive approximations. The fundamental equations and boundary conditions are expressed in differences. Effect of difference magnitudes on the results is also studied.

The solution is given for the case of edges (a) hinged, (b) clamped with free deformation in the direction of the edges, (c) hinged, the edges resting straight. Stresses in the middle plane and flexural stresses are given in tables and diagrams. Results are compared with other methods.

From authors' summary by V. Petrovsky, Czechoslovakia

5294. Brilla, J., Some mixed boundary conditions of anisotropic plates (in German), *ZAMM* **40**, 10/11, 472–482, Oct./Nov. 1960.

Some mixed boundary-value problems of a semi-infinite elastic anisotropic plate $y > 0$ are analyzed. The plate is simply supported along a part of its boundary and clamped along the remainder. From a general solution of a semi-infinite anisotropic plate obtained by the method of Fourier integrals, where the first derivatives of the transverse displacement are given along the edge, a singular integral equation is derived for that boundary-value problem. After reduction of the singular integral equation to the Hilbert-Riemann problem the general solution for n sections of the simply supported edge, loaded by constant moment or concentrated moment, is developed.

Author solves the problem of the semi-infinite plate clamped along $y = 0$, except a section L, where the plate is simply supported. The plate is loaded in this case by a concentrated moment or by a concentrated force in an inner point.

The formulas of the internal forces are calculated without numerical example. S. Sarkadi Szabo, Hungary

Buckling

(See also Revs. 5279, 5289, 5309, 5408)

5295. Renton, J. D., A direct solution of the torsional-flexural buckling of axially loaded thin-walled bars, *Struct. Engr.* **38,** 9, 273–276, Sept. 1960.

The general solution for buckling load presented in this paper differs from previous solutions (for example, those of Goodier and Timoshenko) in that it is not restricted to certain combinations of boundary conditions. The previous solutions have required that the ends be free to warp as well as to bend or else that the ends be completely fixed against both warping and bending.

The author compares his solution with the results of tests on aluminum alloy channel and tee sections made by Baker and Roderick. End conditions for the tests were that bending and twisting moments were zero and that displacement of the centroid and warping were prevented. Baker and Roderick obtained approximate values of critical load by using Timoshenko's equation for the buckling load and assuming that the terms in the equation that represent the critical loads for bending in two directions could be calculated on the basis of simply supported ends and that the term representing the critical load for failure in pure torsion should be calculated as though the ends were fixed. The author's general solution agrees better with the test results than does the approximate solution of Baker and Roderick, although the difference between the critical loads obtained by the two methods amounts to only a few per cent.

Application of the author's solution to the buckling of frameworks is discussed briefly. J. W. Clark, USA

5296. Leipholz, H., Buckling of twisted bars subject to the pressure of a conservative, continuous and uniformly distributed loading (in German), *Ing.-Arch.* **29,** 4, 262–279, Aug. 1960.

Similar problems were treated previously for the case of bars loaded at both ends. In this paper the axial load is uniformly distributed along the longitudinal axis of bar and is assumed to remain parallel to the original position during flexure.

Author assumes that the bar is originally twisted a constant angle per unit length, the longitudinal axis through centroid being straight. The two principal moments of inertia may differ, but are constant along the bar length. Reviewer finds that, according to equations, the center of twist (shear center) must be located at centroid, which is the case by double symmetrical cross sections.

Using equations of equilibrium for an elastically deformed bar element author reduces the problem to the solution of two linear differential equations with variable coefficients. The eigenvalue problem involved is discussed for different end conditions.

S. E. Kindem, Norway

5297. Kats, I. L., On the analysis of critical stress of compressed bars beyond the proportionality limit (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 2, 171–173, 1959.

Author discusses the problem of the buckling of a straight bar beyond the elasticity limit by using the reduced elasticity modulus of Engesser-Karman type for the determination of critical loads. Three different cases are considered, for which the curvature of the mean deformed fiber of the bar in its second equilibrium form (under the effect of bending moments) changes its sign along the bar. P. P. Teodorescu, Roumania

5298. Kee, C. F., Lateral inelastic buckling of tied arches, *Proc. Amer. Soc. Civ. Engrs.* **87,** ST 1 (*J. Struct. Div.*), 23–39, Jan. 1961.

Author reviews briefly Godden's method [*Proc. Instn. Civ. Engrs.*, Part III, Aug. 1954] for lateral elastic buckling of curved arch under downward distributed load. In Godden's method, energy method was used. The assumed sidewise deflection mode consists of a simple sine function and the critical end compressive load can be expressed in terms of the bending and torsional rigidities and the span of the curved arch.

Author then extends Godden's method to lateral inelastic buckling of curved arches by method of successive approximation. For trial values of the bending and torsional rigidities, the critical end buckling load can be calculated using Godden's method. The bending rigidity in the plastic range can then be determined by using either the tangent modulus or the double modulus formula. For simplicity the author assumes that the ratio of bending and torsional rigidities remains the same as that for the elastic range. Experimental results indicate that the buckling loads are more closely related to those obtained by the tangent modulus theory than those evaluated under the double modulus theory. Author also finds that Southwell's method for prediction of buckling loads does not apply very successfully in the inelastic range.

T. H. H. Pian, USA

5299. Karamyshkin, V. V., Stability of circular arcs (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 6, p. 171, Nov./Dec. 1960.

Author gives short continuation of his previous paper [AMR **13**(1960), Rev. 3344] concerning stability of circular arcs with variable moment of inertia. Some new cases of reduction to hypergeometric equation were found, and several errors in the mentioned paper corrected. M. Życzkowski, Poland

5300. Goldberg, J. E., Buckling of one-story frames and buildings, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 10 (*J. Struct. Div.*), 53–85, Oct. 1960.

Author first considers the buckling strength of plane, one-story rectilinear frames, developing the necessary equations by the slope-deflection method. Buckling either with or without sidesway is considered, and in the former case the effect of a restraining force corresponding to the presence of a linear spring is introduced. It is shown that these concepts can be used in the analysis of one-story building structures consisting of a number of parallel frames interconnected by a horizontal truss or roof deck at the level of the tops of the frames. The truss or deck carries shear to shear walls or braced frames at the ends or at intermediate points. In a numerical example, an iterative procedure is used to solve the buckling equations for a building consisting of four two-bay frames connected to each other and to shear walls at the ends by a horizontal truss. J. W. Clark, USA

5301. Mitchell, L. H., and Head, A. K., The buckling of a dislocated plate, *J. Mech. Phys. Solids* **9,** 2, 131–138, Apr. 1961.

The buckling of a free circular plate is investigated theoretically when (a) a sector is inserted into the plate, (b) a sector is removed, and (c) a narrow untapered strip is inserted along a radius. Upper and lower limits are obtained by energy methods and from the governing differential equation.

E. H. Mansfield, England

5302. Wakasugi, S., Buckling of a simply supported triangular plate having inner angles of 30, 60 and 90 degrees, *Bull. JSME* **4,** 13, 16–20, Feb. 1961.

Buckling of the plate described by the title was considered for the cases of a uniformly distributed compressive load and a combination of uniform compressive and shearing loads. For the uniform compression, an exact solution was obtained by combining solutions for a simply supported rectangular plate. In the case of the combined loading, an approximate solution was obtained by Galerkin's method. Some approximate numerical results are presented in graphical and tabular forms. D. Frederick, USA

5303. Wakasugi, S., Buckling of a simply supported equilateral triangular plate, *Bull. JSME* **4,** 13, 20–25, Feb. 1961.

The plate described in the title was considered under a uniform compressive load and a combined uniform compressive and shearing load. For the former, an exact solution in terms of trigonometric functions was obtained, while for the latter an approximate solution was obtained by Galerkin's method. Numerical results are presented in numerical and graphical forms.

D. Frederick, USA

5304. Conway, H. D., and Leissa, A. W., A method for investigating certain eigenvalue problems of the buckling and vibration of plates, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 557–558, Sept. 1960.

The approximate values of critical hydrostatic load for a clamped square isotropic plate and for an equilateral-triangular plate are obtained. The solution of homogeneous differential equation of buckled surface is expressed in polar coordinates. Application of the boundary conditions at only discrete points on the boundary leads to a set of algebraic homogeneous linear equations. The determinant of this set equalized to zero gives the equation of eigenvalues. This method also may be indicated for investigating the vibrations of plates.

Z. Kaczkowski, Poland

5305. Seide, P., Plastic compressive buckling of simply supported plates on interior elastic supports, *J. Aerospace Sci.* **27,** 12, 921–925, 950, Dec. 1960.

Author considers the plastic compressive buckling of rectangular plates on linearly elastic foundations of four types. Solutions are based on a deformation theory of plasticity by Bijlaard and Stowell. Numerical results are given for (a) a uniform foundation, (b) equally spaced transverse line supports, (c) equally spaced longitudinal line supports. A mathematical formulation for the case of point supports or posts is presented without numerical results.

In each case, the plastic buckling loads are referred to the corresponding elastic buckling case. Author also presents a paragraph on the use of a deformation theory of plasticity rather than a flow theory in buckling problems. M. L. Baron, USA

5306. Samuels, J. C., The buckling of circular cylindrical shells under purely random external pressures, *J. Aerospace Sci.* **27,** 12, 943–950, Dec. 1960.

The mean-square stability theory of Samuels and Eringen is applied to the stability of circular cylindrical shells subjected to purely random external pressures. The stability is determined by the character of the roots of a determinantal equation of the 36^{th} degree.

Explicit mean-square stability criteria are developed for a circular ring under purely random pressures. Study showed that all modes of vibration of the ring are unstable for sufficiently large spectral density of the pressure fluctuations.

From author's summary by M. L. Baron, USA

5307. Neuber, H., and Landgraf, G., Plastic buckling of circular cylindrical shells (in German), *Bauingenieur* **34,** 2, 44–48, Feb. 1959.

Theoretical buckling stresses are obtained for circular cylinders of reinforced concrete loaded in either axial or hydrostatic lateral compression. Approach is that of W. Flügge, except that plasticity corrections are introduced into relations between strains and stress resultants. Reduction factors were chosen on basis of considerations of behavior of homogeneous materials and of computational simplicity. Reviewer considers factors chosen in case of shearing and twisting terms to be questionable, but author states that results are not strongly influenced by the choice. Buckling curves are shown for variety of dimensions of particular types of anisotropic cylinder. No experimental data are included.

S. B. Batdorf, USA

5308. Mansfield, E. H., Leading-edge buckling due to aerodynamic heating, Aero. Res. Counc. Lond. Rep. Mem. 3197, 20 pp., 1960.

Author considers the problem of spanwise buckling of thin wings due to chordwise temperature distribution resulting from aerodynamic heating. The wing is considered as a plate of variable bending rigidity along the chordwise direction. The leading and trailing edges are assumed to be sharp edges.

Author uses an inverse method of solution in which a "critical buckling stress distribution" appropriate to a given wing section is investigated. This critical buckling stress distribution has the unique property of causing buckling of leading and trailing edges simultaneously with over-all buckling in torsion or flexure. By comparing this critical stress distribution with the actual stress distribution due to aerodynamic heating one can then conclude whether leading-edge buckling will occur before or after over-all buckling.

Author also shows that leading-edge buckling occurs when the spanwise stress at the leading edge equals $G\beta^2$, where G is the shear modulus of the material and β is the angle at the leading edge formed by tangents to top and bottom surfaces. Other conclusion is that at the onset of leading-edge buckling the spanwise wavelength is very small.

Author also investigates the postbuckling behavior of the leading-edge waving mode using large deflection theory.

T. H. H. Pian, USA

Vibrations of Solids

(See also Revs. 5195, 5197, 5304, 5335, 5385, 5402, 5406, 5527, 5700, 5702, 5703, 5737, 5781)

5309. Burgreen, D., End-fixity effect on vibration and instability, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 6 (*J. Engng. Mech. Div.*), 13–28, Dec. 1960.

Four subdivisions of the subject stated are investigated for uniform beams which, at the ends, have arbitrary elastic restraint in rotation and no lateral displacement:

(a) Static instability (which results from negative end fixity) of beams with no end loads.

(b) Static instability of beams with end loads.

(c) Vibrations of beams with no end loads.

(d) Vibrations of beams with end loads (up to the critical buckling load).

Relationship between column load capacity and beam frequency is examined and an approximate expression relating the buckling load and the vibration frequency of the unloaded column is suggested. J. G. Eisley, USA

5310. Jullien, Y., Vibrations of beams with discontinuous loading (in French), *Acustica* **8,** 4, 201–211, 1958.

5311. Leipholz, H., Critical speeds of shaft under torsion and load due to its own weight (in German), *ZAMP* **11,** 6, 455–471, Nov. 1960.

Method is presented for calculating critical speeds by taking into account the weight of the shaft. The computed example indicates that the critical angular velocities for continuously loaded shafts are larger than those for shafts loaded at the ends with a single concentrated load of the same magnitude.

H. H. Hilton, USA

5312. Bufler, H., and Kiessling, F., Homogeneous machines with additional rotating masses (in German), *Ing.-Arch.* **29**, 4, 250–259, Aug. 1960.

It is known that the problem of the torsional vibrations of homogeneous shaft with several equal disks and equal torsional stiffness of the parts of the shaft between two neighboring disks can be solved by means of the method of the equations of finite differences. In this case the frequency equation can be expressed by elementary trigonometrical functions or the eigenfrequencies can be determined by means of Grammel's frequency function. On the contrary when the shaft has one or more additional rotating masses (flywheels) on one or both ends the problem of computation reduces to the transcendental frequency equation. For the crankshaft of a multicylinder engine the difference between angular displacements of two neighboring disks depends not only on corresponding torsional moment acting on this part of the shaft but also on all other torsional moments (adverted torsion). Assuming that the influence of adverted torsion on the basic frequencies is very small, authors determine the conditions when the complex frequencies exist, giving the corresponding equations for their determination and also corresponding formulas for torsional moments and angular displacements. Three cases of homogeneous shaft (with n disks) are treated: (1) with one flywheel on the end; (2) with two flywheels on one end; (3) with one flywheel on each end. To illustrate the theoretical investigations of above cases three examples with six-cylinder engine are discussed with stiffness ratios $c/c_4 = c/c_9 = 1/3$; $c/c_7 = 1$; and with inertia ratios $J/J_7 = J/J_9 = 1/10$; $J/J_4 = 1/50$. The higher eigenvalues for these examples are determined graphically.

D. Raskovic, Yugoslavia

5313. Rastrigin, L. A., Some features of nonstationary motion of a flexible shaft with a driver as an autonomous system close to the critical speed (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 5, 84–89, 1959.

The behavior of a flexible shaft rigidly connected with a driver in passing through the critical speed is discussed under the assumption that the driver power does not much exceed that necessary to pass through the critical speed.

The solution is extension of the work of Kononenko, but it is not limited by the assumption of the slow process. Author assumes circular shaft and rigid supports; gyroscopical effect of the disk is neglected.

The simplified system of the motion equations has been computed for some parameter values, using analog computer. The results show that less power is needed for nonstationary motion than assumed by the stationary motion.

Limit values of the "dynamic passing-through parameter" are given; to pass through the critical speed it is necessary for the shaft to overstep these values.

The results are of great practical value and make clear some features of rotors in operation.

V. Petrovsky, Czechoslovakia

5314. Kolyadin, G. I., Forced vibrations of the shaft of a motor with consideration for the variability of the inertia moment (in Russian), *Energomashinostroenie* no. 3, 23–25, 1959; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13008.

Equations are derived for the torsional vibrations of the shaft of a motor, account being taken of the variability of the brought-in moments of inertia of the mass. The coefficients of these equations are periodic functions of time. The forced vibrations under the action of harmonic forces through the sine and cosine are investigated. The steady motion is determined by the Bubnov-Galerkin method. It is shown that variability of the moment of inertia does not reduce the vibration amplitudes. It is also shown that combined resonances exist. Formulas are furnished for taking into account the variations of multicylindered motors.

F. M. Dimentberg
Courtesy Referativnyi Zhurnal, USSR

5315. Subramanian, N. R., and Kumaraswamy, M. P., Antisymmetric vibrations of a rectangular plate with distributed added mass, *J. Aero. Soc. India* **12**, 3, 63–68, Aug. 1960.

Using Rayleigh's principle and proving the minimizing properties of eigenfunctions and eigenvalues, authors derive expressions for the lowest frequency of the antisymmetric mode of vibration of the plate. Increasing the distributed mass of the plate decreases the frequency. This result is in good agreement with that obtained for a beam by Handelman. Experimental verification of the solution is proposed.

V. Kopriva, Czechoslovakia

5316. Mazurkiewicz, Z., The problem of bending and free vibration of a simply supported, isotropic, nonhomogeneous, rectangular plate (in English), *Arch. Mech. Stos.* **12**, 4, 497–521, 1960.

Beginning with judiciously chosen and appropriately modified form of plate equation, author obtains associated Fredholm integral equation for simply supported rectangular plate. Transformation of the Green's function to two-dimensional Fourier series leads, finally, to an infinite system of equations in the coefficients of a Fourier series for displacements. Illustrative example of static loading of plate with strong variation of rigidities indicates that convergence could be fairly rapid in certain cases. Extension of basic method to free vibration is described.

J. E. Goldberg, USA

5317. Mitra, A. K., Note on forced torsional oscillation of a circular cylinder by the application of a transient force at one end, *J. Aerospace Sci.* **28**, 3, 246–247 (Readers' Forum), Mar. 1961.

5318. Srinivasan, P., A method for determining the internal damping of rotating disks, Indian Inst. Sci., Golden Jubilee Res. Vol. 1909–1959; 1959, 341–354.

Author extends Cochardt's method [AMR **7**(1954), Rev. 1018] for determining the stress-amplification factor at resonance to the simple case of rotating disks. In the case of the plane stress problem with rotational symmetry, the stress amplitude is a function of the radius only, and the stress-amplification factor can be determined using two quantities: profile function and energy-absorption function. In this case the profile function is simply the thickness of the disk at a given radial distance from the axis. The energy-absorption function can be expressed as a function of the stress amplitude.

Author claims that the radial elongational oscillation may be an important resonant condition for rotating disks and proceeds to calculate the radial and tangential stress-amplification factors for this rotational symmetrical problem. For this vibration problem, author assumes that the stress distribution is the same as that due to the centrifugal forces corresponding to the constant rotating speed.

Reviewer is not aware that the radial elongational oscillation is an important resonant condition. He also fails to see the connection between the radial elongational oscillation and the static stress distribution due to constant rotating speed.

T. H. H. Pian, USA

5319. Srinivasan, P., A method of estimating the environmental damping coefficient of a rotating disc, *J. Aero/Space Sci.* **27**, 4, 312–314 (Readers' Forum), Apr. 1960.

5320. Vidyakin, Yu. A., The damping capacity of the blades of a steam turbine united in a block by means of a band (in Russian),

Energomashinostroenie no. 11, 12-15, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13387.

An experimental investigation was carried out on the title problem. Eight blocks were examined, differing from each other in the number of blades, structural details of the band, etc. The results of the experimental investigation are given in the form of the relation of the vibration decrement to the stresses in the root section of the blade. The author reaches the following conclusions: (1) The damping of the vibrations of the blades united in a block by means of a band is practically independent of the number of blades in the block, (2) The dissipation of energy in the blocks of blades with an attached band exceeds the dissipation of energy in a single blade by 2-3 times in relation to the degree of relative rigidity of the union of blade to band, (3) The damping capacity of the blocks decreases when the ribbon forming the band in addition to its ordinary adhesion is also soldered on. In this case the dissipation of the energy of the vibrations due to friction at the point of union of blade and band is inappreciable, (4) The following relation is observable in the approximate magnitudes of losses of energy of the vibrations in the block: (a) dissipation of energy in the material of the blades 40-50%; (b) dissipation of energy in the material of the bandage 20%; (c) dissipation of energy due to friction in the linkages of the block 30-40%.

V. Kh. Abiants

Courtesy Referativnyi Zhurnal, USSR

5321. Sohngen, H., and Quick, A. W., Vibrations in axial compressors (in German), *Dtsch. Versuchsanstalt Luftfahrt, Ber.* **105**, 36 pp., Jan. 1960.

5322. Kononenko, V. O., On resonance processes in a vibrating system containing a driver (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 2, 75-80, 1959.

Author studies by mathematical methods a coupled vibrating system containing n masses, one of which contains a rotary driver. The driver contains an unbalanced rotating mass. Assuming that the unbalanced mass is small compared to the coupled masses, author can use a small parameter method. By use of normal coordinates, the motions of the various masses can be studied separately as they are affected by the driver. The differential equations of motion are solved approximately using the method of averaging. On the basis of the approximate solutions found the author discusses various resonant states of the system, including an investigation of stability. An important feature of the author's solution is that the angular velocity of the driver at resonance is not arbitrary but is determined by the solution.

W. S. Loud, USA

5323. Bolgov, A. T., Evaluation of the dynamic damping of torsional vibrations in power installations with piston motors (in Russian), *Naucbn. Dokladi Vyssb. Shkoly. Mash. i Priborostr.* no. 2, 75-79, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13017.

A description is given of the work done in connection with an experimental comparison of the Carr-Mans and V. K. Nechaev theories. The experimental apparatus is also described and the results of the experiments discussed. The experimental material obtained by the author agrees quite well with the Nechaev theory. The practical application of the Carr-Mans theory is not justified because in that theory the role played by the dynamic damping is appreciably magnified at the expense of the irregularity of the rotation of the motor.

A. G. Galanov

Courtesy Referativnyi Zhurnal, USSR

5324. Clark, J. W., and Hagel, W. C., Influence of static stress and temperature on internal damping, *Trans. Amer. Soc. Metals* **52**, 95-115, 1960.

The internal damping of fixed-fixed beam AISI-403, titanium, and ferromagnetic austenitic alloys was measured at vibratory stresses from zero to 35,000 psi at static tension stresses from zero to 19,000 psi in the temperature range of 75 to 1100 °F.

Under a static stress of 19,000 psi, the damping of AISI-403 observed at 500 to 700 °F is reduced by more than an order of magnitude from that measured at zero static stress at 75 °F. Titanium shows very low internal damping under all test conditions. Although the damping of ferromagnetic austenitic alloys decreases less rapidly with increasing temperature than it does in the case of AISI-403, the influence of static stress or magnetic fields causes a more drastic reduction.

From authors' summary

5325. Spence, H. R., and Luhrs, H. N., Peak criterion in random vs sine vibration testing, *J. Acoust. Soc. Amer.* **33**, 5, 652-654, May 1961.

Sinusoidal vibration has practical value as a substitute for random vibration in equipment qualification testing. How and when to employ a sinusoidal substitution is discussed in this paper. In particular, a damage criterion is discussed which relates the number of sinusoidal peaks occurring while passing through a resonance to the number of random peaks exceeding a specified amplitude value.

Formulas are given for the sine-random response relationship, with formulas and a diagram for the random test duration to be used with the amplitude relationship.

From authors' summary

5326. Bouche, R. R., Improved standard for the calibration of vibration pickups, *Experimental Mech.* **1**, 4, 116-121, Apr. 1961.

Wave Motion and Impact in Solids

(See also Revs. 5253, 5737, 5781)

5327. Krzywoblocki, M. Z. v., On the statistical mechanics of wave propagation in nonhomogeneous solid bars (in English), *Bull. Soc. Math. de Grace* **31**, 1/2/3, 119-137, 1959.

Author considers, from a purely mathematical standpoint, the statistical mechanics of wave propagation in solid nonhomogeneous bars, and shows that the general aspects of the technique of Kampé de Feriet are applicable. Work is entirely theoretical and no examples illustrating advantages of technique are given.

R. P. Pearce, Scotland

5328. Feng, S.-S., Reflection of finite amplitude waves, *Soviet Phys.-Acoustics* **6**, 4, 488-490, Apr./June 1961. (Translation of *Akust. Zh., SSSR* **6**, 4, 491-493, Oct./Dec. 1960 by Amer. Inst. Phys., New York, N. Y.)

The paper considers the problem of reflection of a finite amplitude wave in the case when it impinges on the wall at an angle of $\pi/4$. The results, obtained by the method of successive approximations correct to the second approximation inclusive, reveal the following: (1) appearance of a wave of twice the frequency, the amplitude of which increases with distance; this wave is reflected according to linear acoustic laws; (2) the appearance of a wave with a frequency 2ω, no increase in amplitude, and having circular symmetry.

From author's summary

5329. Roseau, M., Diffraction of elastic waves (in French), *J. Math. Pures Appl.* **39**, 2, 173-196, Apr./June 1960.

Author considers the propagation of two-dimensional elastic waves in a homogeneous and elastic medium. This problem necessitates the investigation of a system of partial differential

equations subject to certain boundary conditions. Properties of the solution are studied and, upon transforming the problem to a Wiener-Hopf integral equation, it is shown how the solution can be obtained. E. J. Scott, USA

5330. Fischer, H. C., On longitudinal impact: Part 1, Fundamental cases of one-dimensional elastic impact. Theories and experiments; Part 2, Elastic impact of bars with cylindrical sections of different diameters and of bars with rounded ends; Part 3, Impacted bar connected to anvil or to co-axial tube by friction joints, *Appl. Scient. Res.* (*A*) **8**, 2/3, 105–139; **8**, 4, 278–308, 1959; **9**, 1, 9–42, 1959.

Author reviews and then summarizes the principles of longitudinal impact and wave propagation in bars. Considerations are restricted, however, to waves which are long relative to bar diameter in order to avoid complications which accompany dispersion. These principles are applied to analysis of stress conditions produced by impact in bars having changes in acoustic impedances, and bars subjected to various external restraints. Most of the idealized situations considered have some bearing on practical problems encountered in pile driving, rock drilling, rivet driving, and other technical areas in which wave propagation and percussion play an important role.

Reviewer applauds the author's purpose. A thorough consideration of practical applications of wave-propagation principles in the areas mentioned has been long overdue. In reviewer's opinion, however, the survey of principles is too brief and sketchy to be useful to engineers unfamiliar with the subject, and unnecessary for those already familiar with wave-propagation principles. This criticism applies only to Part I. In all the subsequent parts author is quite partial to graphical constructions, and frequently argues the merits of the graphodynamical solution, as he calls it. Reviewer concedes the usefulness of graphical representation, but found many of the diagrams used by the author more enigmatic than illuminating. This stems in part from the small size of the diagrams, and in part from incomplete explanations. The small size can probably be attributed to over-reduction in printing, and the incomplete explanations can be attributed to a need for terseness brought on by consideration of too many examples. Despite these criticisms, reviewer regards this as a very worthwhile series of articles which contain a wealth of information. Anyone interested in the technical areas mentioned above will find these articles invaluable.

In Part II various special problems are treated making use of the methods outlined in Part I. The most notable problem probably is that of the bar with a neck or swell which was treated in more detail by the author in a previous publication [*Appl. Scient. Res.* (*A*) **4**, p. 317, 1954]. Another problem considered is the increase in area of a bar in several steps. Author shows that for transmission of maximum energy through a section of several steps, if the sections are the same length as the hammer, the areas must change in geometrical ratio. This leads in the limit to an exponential taper. Changes in the cross section of the impacting bar are also considered. It is shown in this problem that under certain conditions tension can be developed in the impacting bar. This is suggested as the possible cause of fatigue failures in certain types of hammers. Some comparisons of theoretical and measured strains are presented. In general these show excellent agreement. Other interesting problems are also considered. Solutions are all presented in graphical form.

In Part III a series of idealized cases of external restraints on the impacted bar are considered. Solution of these problems is intended to provide the groundwork for eventual consideration of the pile-driving problem [see following review]. The number of different examples discussed is so great as to be almost tiring. Reviewer would have preferred fewer examples with more detailed discussion of each. Author has either overlooked, or has chosen not to discuss, some rather important details, as for example, how a frictional force applied at the surface of the impacted bar affects propagation within the bar. Reviewer has found some rather surprising results in this regard.

E. A. Ripperger, USA

5331. Fischer, H. C., On longitudinal impact; Part 4, New graphodynamical pulse method of computing pile-driving processes, *Appl. Scient. Res.* (*A*) **9**, 2/3, 93–138, 1960

For years static bearing capacities of piles have been computed from empirical formulas based upon energy considerations and estimated losses in the transfer of energy from the hammer to the pile. Many formulas have been used and in general the results computed by one formula not only differ from those computed by another, they are not even self-consistent. Different bearing capacities are indicated by a given formula for different methods of driving. Author argues, quite justifiably, that these glaring discrepancies indicate a need for a better analysis. He applies a pulse method, developed in first three parts of this paper, to the solution of the problem. This method gives the same bearing capacity regardless of method of driving and leads to conclusions which are in some cases directly opposite to long-held opinions. Validity of these conclusions is demonstrated by actual pile-driving tests in which the author participated.

E. A. Ripperger, USA

5332. Fischer, H. C., On longitudinal impact, Part 5, Plastic compression of long or short bars (rivets); Part 6, Application of the graphodynamical method to some cases from the literature. Accuracy. Recent experiments, *Appl. Scient. Res.* (*A*) **9**, 4, 213–247; **9**, 4, 248–274, 1960.

The principles of pulse propagation in elastic rods is extended in Part V to stresses beyond the yield point in order to analyze the rivet-driving problem. A bilinear stress-strain curve of the elastic-plastic, strain-hardening type is assumed. It is also assumed that unloading and subsequent reloading take place with the original elastic slope, and that there is no strain-rate effect. By means of graphical constructions the problem of the impact of a thin elastic hammer on a long plastic bar is solved. In reviewer's opinion the graphical method originally given by Griffis in 1943 and later amplified by Karnes ["Stress strain characteristics of materials at high strain rates, Part IV: Experimental and theoretical analysis of plastic impacts on short cylinders," Structural Mechanics Research Laboratory, The University of Texas, 1960] offers a much simpler method for treating plastic impact problems. This is particularly true if a more realistic stress-strain curve is used, and if the author's method for finding the initial impact stress is used.

As he progresses toward the actual rivet problem author also considers the problem of a long rivet with a fixed end, and of a "thick" hammer (diameter larger than the rivet) impacting a rivet with a semi-fixed end. The problem of how to obtain the highest possible efficiency of plastic straining by varying the weight and the velocity of the hammer is considered. This efficiency is achieved if the hammer does not rebound when the wave reflected from the free end of the hammer returns to the impact end. It is readily seen that if a certain plastic strain at the top of the rivet is to be obtained, the impact velocity must be twice the particle velocity at the given strain. The required hammer diameter is readily obtained from the graphical construction, or from simple equations. Some experimental results are shown, and explained by applying the previously developed principles.

In Part VI the results obtained by a number of other investigators are discussed, some modern instruments for pulse measurements are discussed, and some examples of measurements are given. This Part seems to be somewhat superfluous, the original purpose of the series having been accomplished in Parts IV and V.

An errata sheet for all 6 parts of the series is appended to Part VI. E. A. Ripperger, USA

5333. Karunes, B., and Onat, E. T., On the effect of shear on plastic deformation of beams under transverse impact loading, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 107–110, Mar. 1960.

This paper discusses the behavior of a rigid-plastic beam under transverse impact. The analysis takes into account the shear and bending deformations and the translatory and rotatory inertia. A rectangular interaction diagram for bending moments and shear forces is assumed which is similar to the assumption of certain ideal I-section or sandwich beam. The discussion indicates the types of beams with predominant shear or bending deformation. The reader may be interested in two papers to which reference is made by authors: H. H. Bleich and R. Shaw, Columbia University Technical Report no. 20 to Office of Naval Research, Project 360.002, 1957; and M. G. Salvadori and P. Weidlinger, *Proc. ASCE* paper no. 1389, 1957. M. P. Bieniek, USA

5334. Karunes, B., and Onat, E. T., Plastic-wave propagation effects in transverse impact of membranes, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 172–176, Mar. 1960.

This paper presents the analysis of motion of an infinite membrane strip attached to two parallel supports under uniformly distributed transverse impulse. The material of the membrane is assumed to be rigid-strain-hardening. The analysis takes into account the effects of transverse and longitudinal waves.
M. P. Bieniek, USA

5335. Hu, H.-C., On reciprocal theorems in the dynamics of elastic bodies, and some applications (in English), *Scientia Sinica* **7**, 2, 137–150, Feb. 1958.

Author discusses reciprocal theorems in the dynamics of elastic bodies and structures, through the use of the Laplace transform. Anisotropic and nonhomogeneous linear, elastic bodies are first considered. Extension is then made to linear bodies with damping. Interesting applications to problems of theory of elasticity, theory of structures, and vibration isolation are given.
Y.-Y. Yu, USA

Soil Mechanics: Fundamental

(See Rev. 5758)

Processing of Metals and Other Materials

(See also Revs. 5373, 5377, 5387)

5336. Hattori, T., Taira, Y., Sogi, R., and Tamai, A., A treatise on the screw extrusion of thermoplastics: Parts 3 and 4, Some examinations on the kneading effect by the screw; Experimental studies about the extrusion of polyvinyl chloride, *Bull. JSME* **4**, 13, 102–114, Feb. 1961.

Part III is concerned with the "kneading" of thermoplastics in screw extrusion so as to obtain a homogeneous structure. It is shown by elementary hydrodynamic arguments that the mean rate of shear can be determined from the ratio between the flow rate and the drag flow. Hence the total amount of kneading can be inferred from the distribution of this ratio along the screw.

In Part IV experimental studies on polyvinyl chloride are reported in detail, in particular the influence of screw shape and speed. R. Hill, England

5337. Grigoryev, B. V., Some problems in flanging and beading membranes, NASA TT F-32, 13 pp., June 1960.

Paper deals with the stress analysis of corrugating membranes by the hydraulic method which is considered to be superior to stamping and other conventional methods. Equations for determining the stresses in the rim and its vicinity during beading and flanging are given. Determination of the required pressure for the process is described. Analysis is illustrated by a numerical example. The design of a hydraulic chamber for corrugating membranes is given. L.-W. Hu, USA

5338. Shaw, M. C., Cook, N. H., Smith, P. A., and Usui, E., Free machining steel: Part 1-3, Tool-life characteristics of resulfurized steel; Tool-life characteristics of leaded steel; Cutting forces; surface finish and chip formation, *ASME Trans.* **83** B (*J. Engng. Industry*), 2, 163–193, May 1961.

Tool-wear and tool-life characteristics of a series of five steels of different sulfur content are presented for different values of cutting speed, feed, cutting fluid, and cold work. While the presence of manganese sulfide in steel is generally found to extend tool life, certain combinations of speed and feed yield results that indicate the reverse effect. For the group of hot-rolled steels studied, sulfur was found to shorten tool life at certain cutting speeds when the feed was in the vicinity of 0.005 ipr. The hot-rolled steels of low sulfur content exhibit better tool life with high-speed steel tools than with carbide tools when the cutting speed is such as to give a tool life in the vicinity of 4 hr. A tracer device is described that is useful in exploring the nature and extent of the crater and built-up areas on the tool face.

High-speed steel tool life results are presented and discussed for a leaded and nonleaded steel from the same heat. Variables investigated include cutting speed, feed, cutting fluid, and cold work.

Tests upon a variety of friction sliders reveal that, contrary to common belief, manganese sulfide is a poor solid lubricant relative to air. Lead, on the other hand, is found to be an excellent solid lubricant. An analog tool is introduced to enable surface finish studies to be made in the absence of feed marks. Cutting force results are presented for a wide variety of cutting conditions for both resulfurized and leaded steels. The built-up edge and thermal softening along the tool face lead to complex curves of cutting force versus speed. Additions of sulfur are found to promote the formation of a small built-up edge that is stable to much higher values of speed than that normally experienced with a nonresulfurized steel. Lead, on the other hand, tends to prevent built-up edge formation. Both lead and sulfur are found to produce thinner chips, promote chip curl, and to give rise to a shorter contact length between chip and tool. A discussion of the significance of the observed changes in contact length will be found in part 4 of this series. From authors' summary

5339. Shiozaki, S., The effect of the relative displacement between the grinding wheel and the work on the wheel depth of cut in grinding operation, *Bull. JSME* **3**, 10, 206–212, May 1960.

Author sets out the geometrical relationships between wheel feed, work and wheel (elastic) displacements and surface roughness for various grinding conditions. True depth of cut is calculated on the premise that total relative elastic displacement of wheel and work is linearly proportional to true cut. Maximum surface roughness is calculated from a formula proposed previously by the author relating roughness at the n^{th} pass to that at the $(n-1)^{th}$. Experimental work broadly confirms the derivations made on depth of cut but not for roughness after a number of passes. J. F. W. Bishop, England

5340. Cole, R. R., An experimental investigation of the electrolytic grinding process, *ASME Trans.* **83** B (*J. Engng. Industry*), 2, 194–201, May 1961.

Data are presented covering the effect of several variables on grinding rate for the electrolytic grinding process. The relative amount of material removal due to electrolysis and due to conventional grinding action was investigated. The Faraday current efficiency of the electrolytic part of the process was found to be near 100 per cent to the extremely high current density of 700 amps per sq in. This is thought to result from the scraping action of the wheel abrasive which prevents passivation of the work anode. Several phenomena of the process are explained on the basis of hydrogen gas pressure in the work-wheel interface. A formula is presented for calculating the hydrogen gas pressure. Equations are proposed for the basic chemical reactions of the process.

From author's summary

5341. Roubik, J. R., A milling torquemeter of planetary-gear design, *ASME Trans.* **83** B (*J. Engng. Industry*), 2, 155–162, May 1961.

A design of planetary-gear dynamometer or torquemeter, to measure tangential cutting forces in milling with a high degree of accuracy and sensitivity, is described together with certain design considerations and limitations as well as associated force-measuring equipment.

This device is a highly efficient, sensitive, and durable research tool for use in accurately determining the magnitude and manner of variation of the cutting force, energy, and power at the cutting edges of single-point or multiple-point milling cutters, as well as machine efficiency, in full-scale milling operations.

Procedures and methods of determining values of tangential cutting force, specific cutting energy, and horsepower at the cutter from cutting-test data obtained with the torquemeter are given with examples.

From author's summary

Fracture (Including Fatigue)

(See also Revs. 5246, 5377, 5378, 5380, 5384, 5387, 5393, 5666)

5342. Ito, K., Photoelastic-plastic studies on brittle fracture of high-polymer solids, *Experimental Mech.* **1**, 5, 159–168, May 1961.

Author has conducted a series of experiments on cast resin tensile and bending specimens and correlated the number of fringes with brittle fracture under maximum tensile stress. In calibrating his experimental materials he finds linear correlation of birefringence with tensile strain for resins of three-dimensional cross-linked polymers such as celluloid. Fracture data are given in tension and compression for thin flat bars with a central hole. Author suggests use of brittle plastic specimens to determine elastic stress concentration factors.

M. L. Williams, USA

5343. Volodina, T. A., Gordeeva, T. A., and Fridman, Ya. B., A method of studying the microgeometry of a fracture surface, *Indust. Lab.* **25**, 8, 1029–1034, July 1960. (Translation of *Zavod. Lab., SSSR* **25**, 8, 984–989, Aug. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Authors refer to studies of fracture surface roughness observations and surface profile measurements, carried out by specified methods in order to give correlations between roughness characteristics and crack-propagation behavior for different machine design steels. The investigation is mainly concerned with components and test pieces subjected to repeated "smooth" stress amplitudes and in some cases with impact stress development. Authors claim that rather stringent correlations can be introduced between type of stress variation and crack-propagation speed and give some illustrative remarks upon the difference in roughness behavior for sharp-notched and unnotched specimens.

Reviewer is impressed by the explanatory efforts which are made to get significant results interpreted from broadly scattered test points and will acknowledge that it might be possible to get some valuable probability correlations established for ranges of steel types rather than for individual steels. Anyway it might be stated that observations of fracture surface roughness form one of the important informations which should be taken care of by the interpretation of rupture phenomena.

R. Nilson, Sweden

5344. Uryu, T., The rate of fatigue-crack propagation in mild steel, Proc. Third Japan Congress on Testing Materials, Tokyo, Sept. 15–16, 1959; Japan Soc. Test. Mat., 1960, 43–46.

This is an experimental study of the stress-dependence of the rate of fatigue-crack propagation in mild steel. Large and small specimens were used to provide size effects. The data are shown to conform to an empirical formula used by Weibull in analyzing fatigue data, namely:

$$\frac{\Delta\lambda}{\Delta N} = C\sigma^r$$

where

$\Delta\lambda$ = increase in crack length
ΔN = corresponding increase in stress cycles
σ = nominal stress
C, r = constants

The data shows C dependent on specimen size, while r is not. Differences in propagation rate are nearly proportional to the square root of the specimen size, though only two sizes were used.

H. I. Fusfeld, USA

5345. Morgan, P. G., The geometry of surface cracks, *Appl. Scient. Res.* (*A*) **9**, 2/3, 148–152, 1960.

The thin surface layers, frequently met with in practice, crack following their cooling in the technological process, as a result of drying or following the corrosive effect of the atmosphere.

This paper establishes a theory which explains the form of the cracks occuring in such surface layers. An observation of the cracks shows that they usually have the form of honeycombs or various polygon patterns.

Several assumptions are made, i.e., the material of the cracked layer is homogeneous, it has the form of a plane surface, during drying or cooling the stresses are uniformly distributed along a line and increase progressively, the cracks are of rectilinear form. By expressing the deformation energy accumulated by the material that deforms and applying the principle of least work, author concludes that the cracks form closed polygonal lines of maximum area. This takes place when the regular or irregular polygon of cracks may be inscribed in a circle whose center lies at the point of no movement of the layer.

G. B. Buzdugan, Roumania

5346. Thurston, R. C. A., Propagating and non-propagating fatigue cracks in metals: Parts 1 and 2, *Engineering Digest* **7**, 2, 21–23, Feb. 1961; **7**, 3, 16–19, Mar. 1961.

5347. Kochanova, L. A., Shchukin, E. D., Likhtman, V. I., and Rebinder, P. A., On the initiation and growth of cracks in strained crystals, *Soviet Phys.-Doklady* **5**, 4, 750–753, Jan./Feb. 1961. (Translation of *Doklady Akad. Nauk SSSR* (*N.S.*) **133**, 1, 71–73, July 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

5348. Bartenev, G. M., and Razumovskaya, I. V., Theoretical strength and critical rupture stress of solid bodies, *Soviet Phys.-Doklady* **5**, 4, 857–860, Jan./Feb. 1961. (Translation of *Doklady Akad. Nauk SSSR* (*N.S.*) **133**, 2, 341–344, July 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

5349. McKenna, J. F., Fracture analysis—A method for solving glass breakage problems in electron tube manufacture, *Bull. Amer. Ceram. Soc.* **40,** 2, 61–65, Feb. 1961.

5350. Feltner, C. E., and Morrow, J. D., Microplastic strain hysteresis energy as a criterion for fatigue fracture, *ASME Trans.* **83** D (*J. Basic Engng.*), 1, 15–22, Mar. 1961.

In this paper an energy criterion for fatigue failure is postulated. Microplastic strain hysteresis is considered to be an index for fatigue damage. On this basis, a relation is developed between stress amplitude and the number of cycles to failure which utilizes only material properties obtained from static true stress-strain tension tests. The analysis is found to compare well with an experimentally determined S-N curve for SAE 4340 steel.

From authors' summary by F. Garofalo, USA

5351. Liu, H. W., Crack propagation in thin metal sheet under repeated loading, *ASME Trans.* **83** D (*J. Basic Engng.*), 1, 23–31, Mar. 1961.

An experimental and analytical investigation was undertaken to study the fundamental factors of crack propagation in a thin metal sheet under repeated axial loading. Sheet specimens of 2024-T3 aluminum alloy containing a central hole were used in the experimental investigation. Stress range and mean stress were the controlled parameters.

An expression for crack length was derived, based on the concept of geometric similarity of crack configuration, for a semi-infinite sheet subjected to repeated loads consisting of a constant stress and mean stress. The expression is in terms of a stress-dependent propagation factor and an exponential function of the number of cycles of loading. The expression for a semi-infinite sheet was modified for crack propagation in a specimen of finite width. Accurate predictions of the propagation life was possible using the modified equation.

Photomicrographic observations of the crack tips were made.

From author's summary by F. Garofalo, USA

5352. Taira, S., and Murakami, Y., On the changes in residual stresses due to repeated stressing, Proc. Third Japan Congress on Testing Materials, Tokyo, Sept. 15–16, 1959; Japan Soc. Test. Mat., 1960, 52–55.

Paper contains results of plane bending fatigue tests with unnotched specimens of 3.2-mm thickness from two unalloyed steels. The maximum values of the initial residual compressive stresses by the shot-peening (steel with 0.44% C) are in the order of 78 kg/mm² and by the low-temperature quenching (steel with 0.16% C) of 10 kg/mm². Both hardening treatments improve the fatigue properties considerably (32.0 or 52.5%). It is concluded that residual stresses are responsible for this behavior. Using an etching method the changes in residual stresses are measured at several distances below the specimen surface after fatigue stressing with stress amplitudes below and beyond the fatigue limit and after different cycles (10^4 to 10^7). In the case of shot-peened specimens the residual stresses are zero after etching off a layer of 0.4-mm thickness. The fading of residual stresses is dependent on material, manner of producing of the residual stresses, alternating stress amplitude and number of cycles.

M. Hempel, Germany

5353. Sawaragi, Y., and Fukuda, M., On the maximum limit of compressive strain in the compressive fatigue test of rubber vibration insulator under constant deflection, Proc. Third Japan Congress on Testing Materials, Tokyo, Sept. 15–16, 1959; Japan Soc. Test. Mat., 1960, 136–138.

Paper describes fatigue behavior of cylindrical rubber specimens bonded on their faces with metal circular plates. The fatigue tests were performed under a constant amplitude of compressive strain from 0 to 25% with the frequency of 500 rpm at room temperature. It has been found that the fatigue cracks develop on the cylindrical surface in the area where compressive strain after having reached a certain value causes wrinkles. Generation of these wrinkles is not influenced by whether the strain is static or dynamic. Results of experiments are worked out in diagrams, showing mutual dependence of parameters involved. Paper is of interest for rubber vibration-insulator design.

V. Kopriva, Czechoslovakia

5354. Lubahn, J. D., Experimental determination of energy release rate for notch bending and notch tension, *Proc. Amer. Soc. Test. Mat.* **59,** 885–915, 1959.

Energy release rates are determined experimentally for notched square cross-section beam in pure bending and notched cylindrical bar in simple tension. Method involves plotting load-deflection curves for unnotched specimens and for a series of notched bars. That portion of deflection due to notch, i.e., excess over unnotched deflection for any given notch, is the basis for derivation of energy release rate. Results are presented as a function of notch depth. Critical energy release rates are obtained using data from fracture tests.

Author concludes that: (1) Agreement between experimental and analytical values of energy release rate is good up to 20% notch depth in bending; (2) experimental values are about 40% higher than analytical values in tension; (3) the Griffith-Irwin critical energy release rate agrees with corresponding experimental value where plastic flow has not been great.

Experimental procedures are discussed in much detail. Derivations and mathematical background are appended.

A. G. Sharp, USA

5355. Crum, R. G., Fatigue in metal joints: Part 1, Mechanical joints, *Mach. Design* **33,** 7, 108–113, Mar. 1961.

5356. Cox, H. L., and Owen, N. B., The influence of biaxial mean stresses on the failure of tubes by fatigue, *Aero. Quart.* **12,** 1, 1–33, Feb. 1961.

Experimental Stress Analysis

(See also Revs. 5278, 5342, 5352, 5356, 5725)

5357. Rocha, M., and Serafim, J. L., The problem of the safety arch dams—rupture studies on models (in Portuguese), Minis. Obras Publicas, Lab. Engen. Civ. Lisboa, Publ. no. 142, 14 pp., 1960.

Rupture tests of models of arch dams provide a means of judging their safety by a way other than the determination of the elastic stresses. Analysis of the various conditions that can produce rupture of a dam indicates that the most probable cause of the rupture of an arch dam is weakness of concrete or of foundation rocks. This means that the models must be loaded with the hydrostatic pressure and the weight should increase in the same proportion till rupture.

The safety factor of a dam should be defined as the ratio between the actual compressive strength of the concrete and the hypothetical strength of a concrete for which rupture occurs under normal loads. Such a safety factor can be determined in the models.

Another very important factor can also be determined with rupture tests of models. This is called factor of adaptation and is defined as the ratio between the maximum stress in the structure that occurs under the maximum design loads and the compressive strength of the material for which the rupture of the dam would take place.

Conditions of similarity to be fullfilled by models are discussed. The definition of the properties of the materials of the prototypes and of the models is considered.

Systems of jacks allow the application of inclined forces corresponding to the hydrostatic pressure and the weight on the upstream face of the models. By increasing the pressure in the jacks those forces are increased until the rupture of the models occurs.

The first results of the tests carried out on the models of arch dams indicate very high safety factors (above 10) and also important factors of adaptation. From authors' summary

5358. Nichols, R. T., Testing techniques for full-scale missile structures under simulated re-entry environment, *Experimental Mech.* **1**, 1, 8–15, Jan. 1961.

The intricate pattern of stresses and strains induced in missile structures by the combined environments encountered during reentry of the earth's atmosphere has necessitated the establishment of unique testing techniques and facilities for evaluating missile performance during this severe phase of flight.

From author's summary

5359. Shimoda, H., Photoelastic investigation of stresses caused by notches in reinforced bars, *Bull. JSME* **4**, 13, 1–5, Feb. 1961.

Bars having a stringer of metal sheet in the central line, and semi-circular or V-notches on both sides, are investigated photoelastically. The bars are made of epoxy resin and stringer of metal sheet (duralumin or copper), which are bonded together with Araldite 121.

The bars are tested under tension with the simple polariscope. The radii (or depths) of the notches of the bars are varied in several values. Consequently, several interesting results are obtained. Then the problem of reinforced bars having a reinforcement of different materials is studied.

From author's summary

5360. Guernsey, R., Photoelastic study of centrifugal stresses in a single wheel and hub, *Experimental Mech.* **1**, 1, 1–7, Jan. 1961.

Results of a photoelastic study of centrifugal stresses in a single wheel with integral hub are given. Stress distributions are determined on the bore and lateral surfaces, and on several radial interior lines.

Methods of calculation based on the generalized plane-stress equations fail to give a true picture of the actual stress distribution on individual radial lines. The discrepancy is particularly large near the junction of wheel and hub. At the bore surface, the calculated stress may underestimate the true maximum stress by 10 to 15%.

From author's summary by T. J. Dolan, USA

5361. Kostak, B., A photoelastic analysis of thin plates subjected to bending (in Czech), *Stavebnicky Casopis* **9**, 1, 5–28, 1961.

A method is discussed which uses the frozen-in stresses and does not require the use of optically isotropic material. The model is made of a plastic. After freezing it is either milled off up to the middle surface, or it may be made of two plates which are glued together and after the freezing taken apart. Models treated in this way are then investigated in a polarized light perpendicular to the middle surface of the plate. In the first case one and in the second case two equivalent parts are obtained on which isoclinics and isochromatics are investigated.

The possibilities offered by this new method are illustrated by the example of a circular plate loaded in its center and freely supported along its edge.

Finally, the separation of principal bending moments from measured values is derived. From author's summary

5362. Prigorovsky, N. I., Methods of evaluation of strain and transference using plastic models (in Russian), *Vestnik Mash.* **39**, 1, 56–69, Jan. 1959.

5363. Bokstein, M. F., Zabugina, N. A., Prigorovsky, N. I., and Khurdsudov, G. Kh., Investigation of stresses in large size presses using plastic models (in Russian), *Vestnik Mash.* **39**, 1, 69–74, Jan. 1959.

5364. Bufler, H., Remarks on the complete evaluation of the state of stress in plates with the aid of photoelasticity (in German), *Ing.-Arch.* **29**, 2, 150–152, Apr. 1960.

5365. Ohasi, Y., Photoelastic examination of Neuber's solution for notched-bar under tension or bending, *Mem. Fac. Engng., Univ. Nagoya* **11**, 1/2, 45–53, Nov. 1959.

Neuber's formula of the stress concentration factor for a notched bar under tension or bending is examined by means of the photoelastic method. Experimental results indicate that his formula can be used for an accurate evaluation of the stress concentration factor only with caution since it gives a small value for notches of medium depth and a large value for shallow notches.

From author's summary

5366. Durelli, A. J., and Daniel, I. M., A nondestructive three-dimensional strain-analysis method, *ASME Trans.* **83** E (*J. Appl. Mech.*), 1, 83–86, Mar. 1961.

Method is based on thin grid embedded in transparent model. Photographic records are taken at several loads and enlarged. Displacements of the grid are measured to an accuracy of one micron. Strains are then obtained by differentiation. Furthermore stress-strain relations furnish the principal stresses; however precision will depend critically on Poisson's ratio as it approaches 0.5. The case of a sphere was found to be in satisfying agreement with theoretical and with photoelastic results.

P.-P. Heusinger, Germany

5367. Tanaka, K., and Nakashima, M., Strain measurement by photography, Proc. Third Japan Congress on Testing Materials, Tokyo, Sept. 15–16, 1959; Japan Soc. Test. Mat., 1960, 161–163.

Paper describes method of measuring strains by measuring angles of interference fringe pattern formed by superimposing a rectangular master grid over the strain distorted grid previously printed photographically on the unstrained specimen.

H. Grover, USA

5368. Post, D., and Zandman, F., Accuracy of birefringent coating method for coatings of arbitrary thickness, *Experimental Mech.* **1**, 1, 21–32, Jan. 1961.

Rational concepts of the behavior of birefringent coatings are developed for both plane-stress problems and general surface-strain problems. For plane stress in elastic bodies, accuracy of stress or strain determinations along free boundaries is almost entirely independent of coating thickness; however, where Poisson's ratios of coating and structure are unequal, the state of stress in the structure might be influenced by the presence of the coating. In experimental investigations of four geometrical discontinuities with coating thicknesses up to 0.9 in. and materials of unequal Poisson's ratios, no influence of coating thickness on boundary strains was observed. For some three-dimensional problems, local shear tractions developed at the interface introduce a dependence upon coating thickness, but the resultant error in strain determinations was approximately 5% for a case studied experimentally.

From authors' summary by T. J. Dolan, USA

5369. Rybakova, L. M., A new method for the superposition of a dividing grid on test samples (in Russian), *Zavod. Lab.* **24**, 11, 1392–1394, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12853.

A method is proposed for laying thin grids on the surface of the sample being studied by the use of the vacuum-cathode method for the investigation of deformations. This method of application of the grid and the apparatus used for the purpose are similar to the method of obtaining replicas for the electron microscope. The original of the grid, in itself a metallic network, is placed on the surface of the sample, transferred under a vacuum bell in which a wolfram spiral is also placed. The metal in dust form lodges on the wolfram spiral. When current is turned on through the spiral the spiral heats up and melts the metal lodged on it, vaporizes it and the metal settles on the surface of the sample. As the original grid is between the spiral and the sample the surface of the sample gets a shadow impression of the grid. The author succeeded in dusting the grid with gold, antimony and other metals on samples made of aluminum and Armco-iron with dimensions for the mesh of 0.2, 0.4, 0.04 mm with a thickness for the filament of 0.1, 0.02 and 0.005 mm respectively. B. P. Sokolov

Courtesy Referativnyi Zhurnal, USSR

5370. Pogorelov, Yu. D., Investigation of the stressed state of a plate of stepped outline by optical and electrotensiometric methods (in Russian), Dokladi Mezhvuz. Konferentsii po Ispytaniyam Sooruzh. Leningrad, 1958, 129–137; *Ref. Zh. Mekh.* no. 11, 1959; Rev. 13889.

The stressed state is investigated of multistepped beam walls under the action of loads assigned on the contour. The analytical problem is solved by means of variational methods via the minimization of the potential energy. Test samples made of phenol-aldehyde plastic were tested by the polarization-optical method. The loading was effected by a specially devised lever instrument while the stresses were determined by the strip method. A graph is given of the stresses to cover particular cases. Stresses in test samples made of aluminum were measured by resistance gages. A design is submitted for the construction of improved gages, which showed a divergence in resistance readings of ±0.2% and in sensitivity of ±2%. P. M. Varvak

Courtesy Referativnyi Zhurnal, USSR

5371. Lenskii, V. S., A two-component strain gauge for measuring deformations, fitted with a pneumatic contact (in Russian), *Zavod. Lab.* **25**, 1, 116–117, 1959; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12861.

An apparatus is described which permits simultaneous and independent determinations to be made of the elongation and angle of torsion of a cylindrical test sample when testing for static tension and torsion. Measurements are taken of the mutual transpositions in the vertical and horizontal directions of two points initially located on one of the generatrices of the sample under test. With these points the device, which is fixed on a movable traverse of the test machine, is joined by the edges of clamped lever arms. The changes of position of the levers produced by the sample's deformation alter the clearances in two (correspondingly measured by the deformation's components) lines of flow of compressed air. This results in changes in the pressure of the compressed air which, with the aid of silicon tubes, are converted into motion reflected by means of mirrors into light rays, enabling a continuous record to be made for the diagram of tension and torsion. The apparatus measures 450 × 150 × 265 mm with a measuring base of 19 × 14.5 mm. The accuracy of the measurements was 1.5% of the magnitude to be measured in the range of deformations of up to 5%. V. S. Zhukovskii

Courtesy Referativnyi Zhurnal, USSR

5372. Brainin, E. I., Oscillographic recording of the deformation of steel specimens at the yield plateau, *Indust. Lab.* **25**, 11, 1427–1429, Oct. 1960. (Translation of *Zavod. Lab., USSR* **25**, 11, 1366–1367, Nov. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Material Test Techniques

(See Revs. 5342, 5343, 5351, 5377, 5378, 5403)

Properties of Engineering Materials

(See also Revs. 5234, 5343, 5344, 5350, 5351, 5352, 5353, 5575, 5583, 5720, 5726, 5788)

5373. Richmond, J. C., Coatings for space vehicles, First Symposium on Surface Effects on Spacecraft Materials, Palo Alto, Calif., May 12–13, 1959; New York, John Wiley & Sons, Inc., 1960, 92–116.

Article discusses desired thermal emittances by coatings for satellites and space vehicles, together with techniques of application, and physical properties of coatings. The six general types of coatings discussed are: (1) organic coatings, (2) electrodeposited coatings, (3) phosphate-bonded ceramic coatings, (4) porcelain enamels, (5) high-temperature frit-refractory ceramic coatings, and (6) flame-sprayed ceramic coatings. Definition of terms, and general review of emittance along with references are included.

Organic coatings such as rubber and plastics are worthless in space vehicles because such materials undergo molecular distillation and vaporize.

One type of electrodeposited coatings is worthy of investigation. This is Dr. Tabor's (Israel) "black" nickel coating applied over bright nickel substrate. Specimens exhibit high solar absorption and low total emittance at moderate temperatures.

Phosphate-bonded ceramics, conventional types, and porcelain enamels are discussed although no particular merits can be assigned. High-temperature frit-refractory coatings are discussed somewhat at length, including tables of compositions, metal cleaning and surface preparation, etc.

It is apparent that the data are meager concerning thermal-emission characteristics. More data are required for space vehicle applications. C. J. Dezeih, USA

5374. Clauss, F. J., Surface effects on materials in near space, *Aero/Space Engng.* **19**, 10, 16–19, 56, 58–59, 62, Oct. 1960.

A broad but rudimentary review of the surface properties of materials in space environment, with emphasis on long-time operation. Discussion includes radiation and temperature-control characteristics of surfaces; degradation of surfaces due to sublimation, short-wave electromagnetic radiation and erosion by solid particles; and lubrication and wear characteristics of sliding surfaces. P. M. Ku, USA

5375. Ryabinin, Yu. N., Effect of pressure on some properties of solids, *Soviet Phys.-Tecb. Phys.* **5**, 6, 693–695 (Letters to the Editor), Dec. 1960. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* **30**, 6, 739–741, June 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

5376. Vereshchagin, L. F., and Zubova, E. V., Measurement of the shear stress in various substances at pressures up to 100,000 atmospheres, *Soviet Phys.-Doklady* **5**, 5, 1031–1032, Mar./Apr. 1961. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **134**, 4, 787–788, Oct. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

5377. Grant, N. J., Mechanical property behavior of metals at elevated temperatures, Proc. International Symposium on High Temperature Technology, Asilomar Conference Grounds, Calif., Oct. 6-9, 1959; New York, McGraw-Hill Book Co., 1960, 198-211.

Author summarizes, in a very practical manner, the many concepts that metallurgists employ to explain mechanical behavior of polycrystalline metals at elevated temperature.

The introductory section "Deformation and fracture" deals with the relationship of stress and temperature on the one hand to creep rate and rupture time on the other. The changing mode of fracture from transcrystalline to intercrystalline is described without using the term "equicohesive temperature." True elongation (at the end of the second stage of creep) is discussed. Reviewer expected here some comments on its relation to the uniform elongation in a simple tensile test.

The next section discusses "High temperature testing" very effectively. Attention is paid to the methods of heating (self-resistance, induction, radiation) and the effect of these heating methods on the ductility due to their effects on the growing microcracks. Attention is also paid to the effect of atmosphere on mechanical properties. An oxidizing temperature is frequently quite beneficial; important exceptions to this rule are iron and simple steels.

The last section deals with the "Control of the high temperature mechanical properties." Recrystallization temperature can serve as a major guide for the development of improved mechanical properties at elevated temperatures. Other concepts illustrated by good examples are: solid solution alloying, two-phase and multiphase strengthening with aging and without aging; cold working and hot-cold working (above recrystallization temperature but with retained strain energy), grain size effect, and stable-dispersion handling (SAP-type material). F. Forscher, USA

5378. Austin, A. L., and Steidel, R. F., Jr., The tensile properties of some engineering materials at high rates of strain, *Proc. Amer. Soc. Test. Mat.* **59,** 1292-1308, 1959.

An ASTM standard tensile specimen 1/4 in. in diameter and 3 in. in length including threaded ends is machined from the material and is subject to explosive tensile impact by igniting a charge of gun powder in a piston attached to the lower end of the specimen. Load is recorded as a function of time with a pair of wire strain gages attached to a cylindrical steel bar in series with the upper end of the specimen. A small correction (of the order of 5%) is made when necessary for the inertia forces in the steel bar. The silhouette of the specimen just prior to fracture is photographed with a high-speed camera as the specimen and a velocity rod attached to the piston are illuminated with an electronic flash unit to give time intervals between successive frames down to 5.9 microseconds. Specimen diameters at the minimum section of the specimen and height of velocity rod are scaled off from the photographs and are substituted in the usual formulas for strain rate and for impact velocity as a function of time. Results are given for tests on 39 specimens of 5 materials as follows: SAE 1018 cold-rolled steel, 6061-T6 aluminum alloy, titanium alloys C120-AV and A110-AT, and commercially pure titanium at strain rates up to 24,000/sec.

The test data for successive specimens were remarkably consistent so that smooth curves of fracture stress, ultimate strength, per cent reduction of area and per cent elongation as a function of strain rate at fracture could be drawn through the individual points. These curves show that the dynamic fracture stress of the steel and the aluminum alloy increased continually with strain rate up to 22,000/sec, while the per cent elongation and reduction in area increased at first but approached a constant value at the higher rates. The two titanium alloys differed from this by showing a minimum of fracture stress at a strain rate of 11,000/sec followed by a rapid increase beyond this strain rate; a corresponding minimum was found in the per cent reduction in area and per cent elongation of alloy A110-AT, but not in alloy C120-AV. The pure titanium showed a continuous increase in fracture stress with increasing strain rate accompanied by a gradual decrease in per cent elongation. W. Ramberg, Italy

5379. Shelton, A., On the ratio of transverse to axial strain and other tensile properties of a cold-rolled steel alloy, *J. Mech. Engng. Sci.* **3,** 1, 89-104, Mar. 1961.

Tensile tests have been performed on a 0.4 per cent carbon-steel alloy in order to determine the behavior of the lateral/longitudinal strain ratio. The material was cold rolled to produce a number of sheets covering the range 0-80 per cent reduction and test pieces were prepared from strips cut from these sheets at each 15° between 0° and 90° to the rolling direction.

The results are presented in graphical form and show the relationship between true tensile stress *versus* rolling reduction and the corresponding point-by-point equivalent contraction ratio *vesus* rolling reduction. The experimental contraction ratio curve was computed from the strains in two transverse directions and represents the uniform contractions which would be experienced by an isotropic bar. This curve is compared with a theoretical curve which is based on the assumption that a metal flows without change in its permanent volume. The influence of cold rolling on some of the mechanical properties of these metals is also shown.

It is concluded that, provided accurate values of the elastic constants are known, the equivalent isotropic contraction ratio for a given tensile strain may readily be computed. The results show that very small permanent volume changes occur but that it is impossible to obtain absolute values by this method. It is also concluded that large errors can arise in stress analysis problems if the variation in the elastic "constants" with cold work is ignored. From author's summary

5380. Glikman, L. A., and Kostrov, E. N., Influence of the scale factor on the fatigue strength of steel (in Russian), *Trudi Leningr. Inzh.-Ekon. In-ta* no. 23, 27-45, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12720.

A very comprehensive review is furnished of the experimental investigations dealing with the influence of the absolute dimensions of the transverse section on the fatigue resistance. Various hypotheses on the nature of the scale factor are analyzed. The opinion is expressed that the basic reasons for the influence of dimensions on fatigue resistance appear to be the stresses' gradient, the nonhomogeneity of the properties of the micro-interstices and, linked with this, the statistical nature of the process of disruption due to fatigue and also of the part played by the reserve of potential elastic energy. V. P. Kogaev

Courtesy Referativnyi Zhurnal, USSR

5381. Egiz, V. I., The importance of the uniform and concentrated plasticity of steel under tensile load, *Indust. Lab.* **25,** 12, 1561-1567, Oct. 1960. (Translation of *Zavod. Lab., USSR* **25,** 12, 1486-1491, Dec. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

5382. Sparkes, S. R., and Chapman, J. C., Model methods, with particular reference to three recent applications in the fields of steel, composite and concrete construction, *Struct. Engr.* **39,** 3, 85-99, Mar. 1961.

5383. Leybold, H. A., Residual static strength of aluminum-alloy box beams containing fatigue cracks in the tension covers, NASA TN D-796, 25 pp., Apr. 1961.

Static tests were performed on 31 box beams containing fatigue cracks in order to determine their residual static strengths. The beams were constructed of 7075 and 2024 aluminum alloy according

to several designs and employed stringers that were either bonded, riveted, or an integral part of the skin. Beams with stringers bonded to the skin (both materials) had the highest residual static strengths, whereas 7075 beams with integrally stiffened covers had the lowest residual static strengths. Except for the integrally stiffened beams, the skin material did not contribute to the residual static strength of the beams because the crack propagated across the skin before maximum load was reached. For the integrally stiffened beams, crack propagation and failure were synonymous. The test results are compared with predictions of the residual static strength. Fair agreement between predicted strength and actual strength was obtained for all beams tested.

From author's summary

5384. Serensen, S. V., Stepnov, M. N., Kogaev, V. P., and Giatsintov, E. V., Investigation on the dissipation of the characteristics of resistance to wear of aluminum alloys, intended for structural use viewed together with their manufacturing technology (in Russian), *Trudī Mosk. Aviats. Tekhnol. In-ta* no. 35, 124 pp., 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12727.

Questions are investigated on the procedure used in carrying out fatigue tests, undertaken with the object of determining the characteristics of the dissipation of the exponents for the "life" of aluminum alloys; methods are described for the statistical analysis of experimental data; results are given of investigations on the influence of a number of technological parameters for the manufacture of components by pressing, forging and stamping on the dissipation of the "life" characteristics, and also on the influence of the dimensions of the test samples and on the form of the stressed state. All the origins of the dissipation of resistance to wear can be summarized as follows: (1) microscopic (linked directly with structure and not eliminated in testing operations), (2) differences in the conditions of preparation and testing of the samples (which are reducible to a minimum), (3) intermediate factors varying along the length of the test sample (differences in the procedure of thermal treatment and of mechanical treatment, scratches, insets and so forth). It was shown that the dissipation characteristics differ for different alloys and for varying technologies employed in the manufacture and appear to be very important exponents of the reliability with which the constructional strength of an alloy can be judged; they are basically linked with the statistical nature of the very process of disruption itself (the microstructural factors) and can be considered as an internal property of the material. In connection with these considerations a recommendation is made to carry out fatigue tests in corresponding cases using not less than 20 samples at each level of stress followed by a statistical analysis of the results. The necessity for testing a large number of samples at each level of stress is connected with the relation of the mean-square declination S of the "life" N to the stress (S is lowered appreciably with increases in N). Here a further recommendation is made to adopt the magnitude $\lg (N - N_0)$ rather than $\lg N$ (N_0 being "The threshold of sensitivity" by cycles, that is, the number of cycles below which number the complete destruction of the sample is not possible). The determination of N_0 is carried out from the rectilinear relation $(N - N_0)$ to the accumulated frequency of the disruption (on the assumption that the normal principle of distribution of $\lg (N - N_0)$ is operating). The use of other principles for the distribution differing from the normal would be difficult because of lack of tables for these functions. Therefore although the normal principle of distribution is sometimes at fault its use is recommended.

V. N. Geminov

Courtesy Referativnyi Zhurnal, USSR

5385. Mutchler, L. D., Energy absorption of aluminum tubing, *ASME Trans.* **82 E** (*J. Appl. Mech.*), 4, 740–743 (Brief Notes), Dec. 1960.

5386. Vitovec, F. H., Effect of grain size and size of notch on the fatigue behavior of a magnesium alloy (in English), *Schweiz. Arch.* **27**, 4, 163–166, Apr. 1961.

A study was conducted on the effect of grain size, size of specimen and stress gradient on the direct stress fatigue strength of a magnesium alloy at room temperature. Specimens with three different grain sizes and seven different notch sizes were used in this investigation. The data are analyzed with regard to relationships between grain size, size of notch, relative stress gradient, stress gradient per grain, and theoretical maximum strength of notched specimens. The best correlation of the data was obtained by plotting the ratio of theoretical stress concentration factor and effective stress concentration factor as a function of the relative stress gradient.

From author's summary

5387. Widmer, R., and Grant, N. J., The role of atmosphere in the creep-rupture behavior of 80 Ni–20 Cr alloys, *ASME Trans.* **82 D** (*J. Basic Engng.*), 4, 882–886, Dec. 1960.

The effects of atmosphere on the creep and creep-rupture of 80 Ni–20 Cr alloys was studied at 1500 and 1800 °F. It was found that the initiation and propagation of intercrystalline cracks were significantly altered and that, in comparison with an argon atmosphere, air has a strengthening effect in all cases. Methods of melting (air-melt versus vacuum melt) were also found to strongly effect the process of creep rupture.

E. E. Sechler, USA

5388. Pavlov, I. M., and Mezis, V. Ya., Influence of the change of sign in plastic deformation on some of the properties of the metal (in Russian), *Trudī In-ta Metallurgii, Akad. Nauk SSSR* no. 3, 295–306, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12643.

This is a study of the changes in H_B, σ_T, σ_B, δ_s and the microstructure of Cu, Al and Fe in the transition from deformation of constant sign (extending) to deformation of variable sign (extension and subsequent sagging) of the same magnitude. The hardness of Cu and Al is 4–6% lower in extension plus sagging than in extension only. For Fe there is no well-defined relation of H_B to the deformation sign. σ_T, σ_B and δ_s were determined on microsamples 1.5–2 mm in diameter, cut out longitudinally and transversely to the direction of pull. Extension and sagging, as might be expected, produce less toughening in the longitudinal direction than would simple extension. For Al the biggest divergences between σ_T and σ_B were 18 and 15%, respectively. In the transverse direction a greater degree of toughening is obtained by the combined effect of extension and sagging by comparison with extension alone. For Fe the maximum divergences between σ_B and σ_T were 16 and 18%, respectively. This difference is explained by the varied end-forms of the microdefects which appear as concentrators of the stresses. The character of the relation of δ_s to the deformation sign differs for different metals and degrees of deformation. With extension and sagging the microstructure differs slightly from the microstructure of the undeformed metal in contrast to the microstructure with extension.

E. V. Efimov

Courtesy Referativnyi Zhurnal, USSR

5389. Arkharov, V. I., Ivanovskaya, S. I., Kolesnikov, G. N., and Moiseev, A. I., Stress relaxation and the irregularity of diffusional movability in polycrystalline austenite ferrochrome-nickel alloys (in Russian), *Trudī In-ta Fiz. Metallov, Ural'skii Fil. Akad. Nauk SSSR* no. 19, 122–126, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12756.

The hypothesis is investigated that plastic deformation at high temperatures and small velocities of deformation (relaxational processes) is brought about mainly by means of diffusion and is localized in the intercrystallite zones. Here the assumption is made that there must be a correlation between the intensity of the stress relaxation and the diffusional movability. Data were obtained for a series of heat resistant alloys for the relaxation in-

tensity and the diffusional movability of nickel in the intercrystallite zones. Correlation was established between the magnitude of the coefficient of diffusional movability and the intensity of the stress relaxation. Here the use of data on the diffusional movability of nickel at 1100°, notwithstanding the fact that the stress relaxation was evaluated at 550°, was unable to strengthen, and was only able to weaken, the established correlation.

I. A. Razov

Courtesy Referativnyi Zhurnal, USSR

5390. Kolesnikov, G. N., Moiseev, A. I., and Yakutovich, M. V., The influence of small additives of alloying elements on the stress relaxation in ferrochrome nickel alloys (in Russian), *Trudi In-ta. Fiz. Metallov. Ural'skii Fil. Akad. Nauk SSSR* no. 19, 95–100, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12757.

An investigation was carried out on ferrochrome nickel alloys containing 20% Cr, 10, 20 and 40% Ni and also small quantities of molybdenum, wolfram, cobalt, boron, titanium, manganese and niobium. The experiments were carried out on a machine intended for use for testing stress relaxation in tension. The testing was done on samples with a working length of 100 mm and a diameter of 4.5 mm with a uniform value for the initial stress throughout of 13 kg/mm² and at different temperatures from 350 to 850°. The time taken for the test was 12 hours. A comparison of the dependence of the relation of the end stress to the initial stress on the temperature for alloys with different small additives made it possible to determine the character of the influence of these additives on the intensity of the stress relaxation.

Yu. G. Maksimov

Courtesy Referativnyi Zhurnal, USSR

5391. Sakhon'ko, I. M., Plasticity of steels quenched to a high degree of hardness when being tested for compression on short cylinders (in Russian), *Tekhnol. Podshipnikostroeniya* no. 17, 194–195, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12648.

It is shown that the plasticity of steels described in the title can be demonstrated not only by compression tests in high pressure chambers or in plastic bands but also in a simpler way—by ordinary compression of short cylinders with the relation of height b to the diameter D equal to 0.5–0.65. Testing of these samples was carried out by a method of stepped-up compression in special centering apparatus. The additions of load at each step should correspond to an increase of the stress of 20–25 kg/mm². It is recommended that there should be three cylinders which are placed on top of each other and deform simultaneously. Here the middle cylinder is the test sample, the upper and the lower cylinders serving as matrices. The polishing of the samples is carried out after the final thermal treatment. The faces should be strictly parallel, and their cleanliness not lower than the 9th class. The possibility of plastic deformation of hardened steels when tested for compression in short cylindrical test-sample form depends on the fact that the maximum tangential stresses, because of the forces of friction on the faces, are concentrated in the central part of the bulk of the sample, and at this point the overcoming of the resistance of the material to shear already sets in in the stage of elastic deformation of the sample as a whole, thereby aiding the development of plastic deformation. The short cylindrical samples of hardened steel break down after very considerable plastic deformation (up to 35%) with fragmentation as the result (the sample collapses into small pieces). The tests were carried out on steels of marks Shx 15, Shx 15SG, U_8, U_{10} with hardnesses of up to R_c = 62–64.

V. N. Geminov

Courtesy Referativnyi Zhurnal, USSR

5392. Sergeev, G. Ya., Titova, V. V., Savitskii, E. M., Zhul'kova, A. A., and Nikolaeva, Z. P., The mechanical properties of uranium (in Russian), *Atomnaya Energiya* **5**, 6, 618–623, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12782.

Results are described of the mechanical testing of uranium at room and high temperatures. Data are given on the hardness of uranium in the temperature range of 20–600°, on the flow pressure when compressed in the α- and γ-phase regions, on the mechanical properties in tension and impact ductility at the temperatures of the α-, β- and γ-phases. The anisotropic behavior of individual grains of coarse-grained uranium under mechanical testing is reported. It was shown that the presence of allotropic conversions and differences in the crystalline structure of uranium modifications have a marked influence on the uranium's mechanical properties. The relation of the mechanical properties to the uranium's carbon content is pointed out.

B. I. Aleksandrov

Courtesy Referativnyi Zhurnal, USSR

5393. Stephens, J. R., Effect of surface conditions on ductile-to-brittle transition temperature of tungsten, NASA TN D-676, 31 pp., Feb. 1961.

5394. Ivanov, A. M., Long-term strength and the deforming capacity of wood (in Russian), *Sb. Tr. Voronezhsk. Inzh.-Stroit. In-ta* no. 4, 5–23, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 12803.

This presentation on the structural nonhomogeneity is based on the hypothesis that the wood is built up of two phases; particles of the wood are referred to the first phase because their long-term strength is equal to zero, while particles are referred to the second phase as having various values differing from zero. As the result of removing the load off the weak particles in the first phase at the expense of supplementary loading of the stronger particles in the second phase a process of elastic aftereffect is started at the expense of supplementary deformations in the particles of the second phase which proceed with the lapse of time. The author, working on this basis, proposes a method for the drawing of a structural diagram in coordinates σ and $\Sigma\Delta F$. If the load on the wood is chosen in such a manner that the particles of the second phase will be loaded up to the limit of their long-term strength, then the mean stress of the wood σ_* will be equal to its limit of long-term strength

$$\sigma_{lts} = (1 - m)\sigma\max,$$

[*lts* = long-term strength—Translator]. Should the load on the wood exceed its long-term strength the results would be that initially a process of elastic aftereffect would start up to such time as the particles of the second phase are loaded to the limit of their long-term strength; after that point is reached the process of their deformation would proceed as a process of flow with a load on the particles in excess of their limit of long-term strength. The process of relaxation is investigated on analogous lines. In order to obtain an experimentally determined structural diagram it is essential to find the end value for the deformation due to aftereffect for different constant loads, lying lower than the limit of long-term strength for the wood. An experimental investigation of this nature was carried out by the author on air-dried pine wood for compression, tension and shear along the fibers and also for transverse deflection.

F. P. Belyankin

Courtesy Referativnyi Zhurnal, USSR

5395. Huffington, J. D., and Stout, H. P., The friction of fibre assemblies, *Wear* **3**, 1, 26–42, Jan. 1960.

It is shown that for a number of natural and synthetic fibers contact between surfaces during sliding produces deformation of asperities such that the area of contact at a single asperity on the adhesion theory of friction varies with load w as w^m, where m = 0.6. This is close to the value that would be expected for purely elastic deformation of the polymeric material. Frictional measurements under experimental conditions in which the total number of asperities N is independent of the total load W are able to give, as a unique case, the value of m which corresponds to elastic defor-

mation. Fiber assemblies are usually soft and flexible and their friction often involves contact between a relatively large number of asperities as compared, for example, with rigid solids, thus enabling the above unique condition of elastic deformation with a constant N to be approximately realized over a certain range of loads at low loads. More generally N increases with load and this appears in the present experiments to be due to a second type of deformation, the deformation of the fiber assembly as a whole (e.g. yarn, cloth, fringe, etc.) so as to involve an increasing number of fibers in the contact region. This deformation usually follows a simple law which has been investigated for a number of types of fiber assembly. From authors' summary

5396. Gusel'nikov, G. D., Efficiency of steam treatment of concrete under normal pressure (in Russian), *Gidrotekh. Stroit.* **31**, 2, 22–25, Feb. 1961.

On the basis of a large number of cubes tested over a period of years (in particular in a precast slab factory), author recommends:

(1) Isothermal (70 °–80 °C) steam curing of concrete may last not more than 6 hrs (increase of temperature to its maximum also lasting about 6 hrs.). This is much less than the prevailing Russian practice.

(2) The effectiveness coefficient for Portland cement concretes of 300, 400 and 500 kg/cm² cube strength may then be assumed to be 0.75. Practically no difference in mean strength exists after 28 days between cured and non-cured concrete.

A. Zaslavsky, Israel

5397. Mather, B., and Tynes, W. O., Investigation of compressive strength of molded cylinders and drilled cores of concrete, *J. Amer. Concr. Inst.* **32**, 7, 767–778, Jan. 1961.

5398. Carmichael, A. J., and Holdaway, H. W., Phenomenological elastomechanical behavior of rubbers over wide ranges of strain, *J. Appl. Phys.* **32**, 2, 159–166, Feb. 1961.

From general strain-energy functions of Mooney [*J. Appl. Physics* **11**, p. 582, 1940] and experimental data of Treloar [*Rubber Chem. and Techn.* **17**, p. 813, 1944], stress function is

$$\psi(x = (A/2) \exp [\beta(x^{1/2} - x^{-1/2})] - B(x + x^{-1} - 2).$$

Here x is related to extension ratio, while A, β, and B are constants. For a large class of rubbers $A = 15/12$ kg/cm², $\beta = 0.528$, and $B = 0.11$ kg/cm². Good fit to experimental data is obtained for extension ratios to 7 for unidirectional straining, and 5 for two-dimensional stretch. Function gives correct small strain linear behavior. V. Salmon, USA

5399. Gorelik, B. M., Bukhina, M. F., and Sazhenov, A. F., A method of measuring the contact pressure in compression of rubber specimens in a wide temperature range, *Indust. Lab.* **25**, 11, 1435–1437, Oct. 1960. (Translation of *Zavod. Lab., USSR* **25**, 11, 1373–1374, Nov. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Structures: Simple

(See also Revs. 5245, 5253, 5256, 5258, 5262, 5270, 5295, 5298, 5300, 5307, 5335, 5382)

5400. Scordelis, A. C., A matrix formulation of the folded plate equations, *Proc. Amer. Soc. Civ. Engrs.* **86**, ST 10 (*J. Struct. Div.*), 1–22, Oct. 1960.

An analytical procedure, utilizing matrix algebra, is developed for determining longitudinal stresses, transverse moments, and vertical deflections in folded plate structures. The procedure provides an efficient and systematic method for analyzing structures of this type. The sequence of matrix operations can be readily programmed for a digital computer having available matrix subroutines. A sequence which has been programmed for the IBM 704 digital computer is described.

From author's summary by D. M. A. Leggett, England

Book—5401. Stampf, W., Continuous arched girder on elastic supports, with and without stiffening girder [Der durchlaufende Bogentraeger auf elastischen Stuetzen mit und ohne Versteifungstraeger], Berlin, Springer-Verlag, 1960, viii + 196 pp. DM 37.50.

Book deals with continuous arched girders—arrays of arches on columns, looking approximately like aqueducts. In the first part of the book the load is immediately applied on the arches while in the second part the arches are assumed to be spanned over top by stiffening girders which rest on the arches by means of pin-ended stanchions. These two types of structures are used mostly in bridge design. The last part of the book deals with applications in building construction, and therefore leads to analogous systems such as the multi-bay frame.

The highly redundant structure is treated by the slope-deflection method, the unknowns being the slopes and the deflections of the joints between the arches and the supporting columns. Except for shrinking and change of temperature the vertical component of the aforementioned deflection is neglected. The analysis comprehends the influence of loads of different direction (but always in the plane of the structure), break powers, wind pressure, change of temperature and shrinking. Influence lines are calculated. Illustrative numerical examples give valuable hints for practical use. The book may render good assistance to designers of bridges and sheds. F. Chmelka, Austria

5402. Berg, G. V., Response of multi-story structures to earthquake, *Proc. Amer. Soc. Civ. Engrs.* **87** EM 2 (*J. Engng. Mech. Div.*), 1–16, Apr. 1961.

This interesting paper presents the results of dynamic analysis of a 4-story structure subjected to 1935 Helena and 1940 El Centro earthquakes. The computations were executed on an IBM-650 computer. The results presented are displacement response versus time curves and tables showing the maximum magnitudes of the following response parameters: Deflection in inches, Shear coefficient (maximum shear in i-th story/weight of structure), Shear distribution (maximum shear in i-th story/maximum shear in first story), and Seismic coefficient (maximum shear in i-th story/weight of structure above i-th story). The following conditions are considered: undamped elastic frame, undamped elastic-plastic frame, elastic frame together with shear walls and viscous damped frame. A comparison of the results with 1959 Los Angeles Building Code and 1958 San Francisco Code are also given in the tables. As in any other study, this study is limited to a single translational component of ground motion and a single translational component of structural response. K.-K. Chu, USA

5403. Viner, L. Ya., The behavior of eccentrically-compressed short struts under long term loading (in Russian), *Beton i Zhelezobeton* no. 5, 227–231, May 1960.

Author describes tests on 12 small-scale composite columns (15 × 15 × 110 cm prisms reinforced with 4 tied structural angles, reinforcement ratio 4.2%) subjected to a constant sustained compressive load (50–60% of ultimate load) of 10% eccentricity. Duration of loading was up to 520 days.

Tests reproduced conditions prevailing in large-span arched concrete bridges (under construction in the Caucasus) reinforced with structural steel members. Redistribution of stresses due to plastic (yield) deformation of the steel and creep of the concrete is analyzed. Tests indicate that after 100–120 days of sustained loading the most highly compressed steel reinforcement starts yielding.

Despite low reinforcement ratio tests confirm the correctness of the ultimate load formula (as recommended by the Russian Code) for composite columns.

Numerous complementary tests were performed and analyzed (short-term loading, central loading, deformability, different concrete ages, etc). A. Zaslavsky, Israel

Structures: Composite

(See also Revs. 5257, 5267, 5277, 5282, 5288, 5292, 5357, 5373, 5722, 5729, 5783)

5404. Yuditskii, G. A., Experimental investigations of the pulsations of a hydrodynamic load on the slab of a dam's threshold (in Russian), *Izv. Vses. Nauk-i. In-ta Gidrotekhn.* **58,** 107–123, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13631.

A model of a dam was built in order to make direct measurements of the pulsations of a hydrodynamic load in an experimental tank with a width of 0.63m. A choice of top fittings made it possible to vary its height within the limits of 18.7 to 58 cm. Two slabs for the threshold with a width of 52 cm and a length of 70 cm, made of organic glass, were screwed on to a specially suspended rigid steel frame beyond the dam. The observations were made on the slab nearest the dam. The construction of the gages and the measuring instruments is described. The maximum spread of the pulsations of the hydrodynamic load over the whole slab of the threshold was determined by the maximum spreads of the pulsations recorded by the gages. The results of the measurements are given in the form of curves. It is noted that with increase in the extent of the submersion of the shock wave the maximum spread of the pulsations decreases to a certain extent (not more than 11%). V. V. Fandeev

Courtesy Referativnyi Zhurnal, USSR

5405. Ross, C. T. F., The deep girder grillage under a uniformly distributed load, *Shipbuilder* **67,** 635, 619–622, Nov. 1960.

Author derived the solutions for a grillage system of one deep girder associated with several equally-spaced light beams, uniformly loaded and completely fixed at the edges, extending Dr. Muckle's method for the simply supported edges. To introduce partial edge fixity, author suggests a method of interpolation with simple assumption that the reaction between girder and beam will be in linear relation to the fixity. His calculations clearly show the influence of edge fixity to the bending moment.

T. Kanazawa, Japan

5406. Jaworski, A., Stress analysis of thin-walled structures with flexible ring stiffeners, subjected to concentrated loads (in English), *Arch. Budown Maszyn* **7,** 2, 151–197, 1960.

Essential feature of method is representation of the interaction, i.e. the shear flow, between the shell and ring in Fourier series. Amplitudes of zero and first harmonics are determined from equilibrium conditions; the remaining amplitudes are deduced from the Maxwell-Mohr equations. Paper contains a worked example, results of which are in reasonable agreement with experiment.

D. M. A. Leggett, England

5407. Traexler, J. F., Design of pressurized cylinders for high-temperature applications, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 477–481, June 1960.

General equations for the stresses in a thick-walled cylinder in a state of plane strain are derived considering "steady-state" creep. A specific form of the creep-rate function is assumed and numerical examples are included to show the effect of geometry and material properties. From author's summary

Machine Elements and Machine Design

(See also Revs. 5242, 5290, 5313, 5337, 5339, 5341, 5360, 5368)

5408. Blake, A., Analysis of buckling column spring with pivoted ends and uniform rectangular cross section, *ASME Trans.* **83** B (*J. Engng. Industry*), 1, 61–67, Feb. 1961.

Design formulas and working charts are derived for predicting load deflection characteristics and maximum bending stresses in initially straight buckling column springs, of uniform cross section, considered to be pin-jointed at the supports. Load-deflection analysis is based on the study of a slender bar, compressed beyond critical buckling, made by Lagrange. Stresses are calculated using the elementary strength of materials theory. The predicted load-deflection curves for typical spring proportions are compared with the experimental results.

From author's summary by K. Julis, Czechoslovakia

5409. Tovelev, L. B., Minimum weight analysis of cylindrical spiral springs subject to compression (in Russian), *Vestnik Mash.* **39,** 10, 24–29, Oct. 1959.

The problem is to choose optimum dimensions of a helical spring with given minimum force P_{min}, difference of deflections λ, and material constants. Fogel [*Automobiltechnische Zeitschrift* 1948] found in such a case $P_{max} = 2\,P_{min}$. This result, valid if elementary theory of springs is used, was criticized and improved, the influence of bending and curvature of coil being taken into account.

The results are not convenient for applications. Reviewer believes that the use of power series (similar to well-known investigations of Göhner and Chernyshev) would give more convenient formulas. M. Zyczkowski, Poland

5410. Bondy, P., The computation of large bending deformation of straight springs (in Hungarian), *Gep* **12,** 8, 316–320, Aug. 1960.

Elementary strength of materials neglects the $(y')^2$ term in computation of radius of curvature of deflected beams and springs. In case of large deformation this term can no longer be neglected. The rigorous computation is extremely complex. The method followed by the author lies between these two extremes. Tables given in the article facilitate the solution for the most common cases. A numerical example shows the application of the derived method. R. Szilard, USA

5411. Oki, I., Experimental research on disc valves—Experimental formulae for discharge and lifting-force of flat-seated valve, *Bull. JSME* **4,** 13, 87–93, Feb. 1961.

5412. Gazarov, A. T., The synthesis of hinged four-link mechanisms with maximum angles of transmission (in Russian), *Trudi In-ta Mashinoved. Akad. Nauk SSSR, Seminar po Teorii Mash. i Mech.* **18,** 69, 13–17, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13050.

A description is given of the analytical method of synthesis of the optimum articulated four-link mechanisms in which the coefficient of variation of the velocity is other than unity. By the term optimum mechanisms is understood those mechanisms in which the angles of transmission, when the mechanism is occupying an arbitrary position and especially in the region in which the working process is taking place, possess maximum values. This condition has a beneficial effect on the increase of the k.p.d. (efficiency) of the mechanism and on the decrease of the magnitudes of the torsional moments on the crankshaft.

L. S. Grodzenskaya

Courtesy Referativnyi Zhurnal, USSR

5413. Bucci, G. A., Design equations for inverted slider-crank mechanisms, *Mach. Design* **33,** 6, 159–161, Mar. 1961.

Fastening and Joining Methods

(See Revs. 5355, 5373)

Rheology

(See also Revs. 5336, 5687)

5414. Narasimhan, M. N. L., Laminar non-Newtonian flow in an annulus with porous walls (in English), *ZAMM* **41,** 1/2, 44–54, Jan./Feb. 1961.

Author considers a special type of non-Newtonian fluid which is defined by adding some second-order terms to the stress rate of deformation relations of classical hydrodynamics. An exact solution of the flow problem is obtained when fluid is injected at one wall and removed at the same rate as the other. Velocity distribution in the pipe is evaluated numerically. Problem of flow between porous plates is also solved.

A. E. Green, England

5415. Graebel, W. P., Stability of a Stokesian fluid in Couette flow, *Physics of Fluids* **4,** 3, 362–368, Mar. 1961.

Author treats stability with respect to small perturbations of Couette flow of a second-order Reiner-Rivlin fluid. This type of fluid involves one material constant not occurring in a Newtonian fluid, a cross viscosity, which plays a significant role in determining configurations of neutral stability.

J. L. Ericksen, USA

5416. Korol', I. P., Study of viscous flow of rubbers: Part 4, Flow of natural rubber and polyisobutylene as function of the molecular composition, *Soviet Phys.-Tech. Phys.* **4,** 5, 577–581, Nov. 1959. (Translation of *Zh. Tekh. Fiz., Akad. Nauk USSR* **29,** 5, 647–653, May 1959 by Amer. Inst. Phys., New York, N.Y.)

5417. Kearsey, H. A., and Cheney, A. G., A note on the effect of temperature on the rheology of thoria slurries, *Trans. Inst. Chem. Engrs.* **39,** 2, 91–92, Apr. 1961.

Hydraulics

(See also Revs. 5180, 5213, 5404, 5438, 5470, 5482, 5512, 5519, 5559, 5633)

5418. Horst, H. Velocity distribution in open channels at turbulent flow and its relationship to sediment movement (in German), *Deutsche Gewässwerkundliche Mitteilungen, Koblenz* **4,** 3, 63–72, 1960; **4,** 4, 85–92, 1960.

Law of velocity distribution along the vertical in an open channel is derived from an assumption that velocity gradient is proportional to the squared vertical velocity component, resulting in a potential formula $v = v_x(1 - e^{-y/c})$, where v_x is practically the velocity at surface, c is a constant, called roughness. Such formula was proposed in 1898 by W. Kostkiewicz and discarded, as inconsistent. Therefore all conclusions are questionable.

S. Kolupaila, USA

5419. Cooper, A. R., Jr., Effect of aspect ratio and viscosity gradients on flow through open channels, *J. Amer. Ceram. Soc.* **43,** 2, 97–104, Feb. 1960.

The slow flow in an open rectangular channel is investigated for both the cases of constant and variable viscosity with application to the flow in glass tanks and glass-making processes. The viscosity distribution which is temperature-dependent only is obtained from the solution of the heat-conduction equation on replacing the thermal conductivity by an average value and allowing for the difference in thermal diffusivities of the flowing glass and the refractory walls.

Numerical results show that the effect of the variable viscosity on the velocity distribution is large when the maximum relative viscosity, with reference to the free surface value, exceeds about 50, even though the maximum velocity ratio is only increased by a factor of about 3 for a relative viscosity of 500,000. The effect of the side walls is shown to be roughly confined to a transverse distance of about two channel depths for large ratios of width to height.

G. M. Lilley, England

5420. Kopyrin, M. A., Distribution of velocity and pressure of the liquid in a curved channel (in Russian), *Trudi Kazansk. Aviats. In-ta* **33/34,** 31–42, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13656.

The plane problem is examined regarding alteration in the direction of the flow of a liquid by an angle of 90° with the aid of bends formed by two concentric round cylinders. The liquid is considered to be viscous and incompressible; it is assumed that the particles of the liquid move in concentric regions. The pressure at the inlet to the channel and the discharge of liquid are taken to be constant. The conditions of adhesion on the lateral sides of the channel are satisfied. The problem merges with the solution of a single ordinary differential equation of the third order. As the result final formulas are obtained for the distribution of the velocity and pressure at an arbitrary point in the channel. A numerical example is given, together with tables and graphs.

B. N. Rumyantsev
Courtesy Referativnyi Zhurnal, USSR

5421. Taylor, G. I., Deposition of a viscous fluid on the wall of a tube, *J. Fluid Mech.* **10,** 2, 161–165, Mar. 1961.

Measurements of the amount of fluid left behind when a viscous liquid is blown from an open-ended tube are described.

From author's summary by A. G. Fabula, USA

5422. Gerrand, G., Present design trends for high-output penstocks operating under high head; Part 2 (in French), *Houille Blanche* **15,** 5, 601–615, Sept./Oct. 1960.

5423. Yih, C.-S., Finite two dimensional cavities, *Proc. Roy. Soc. Lond.* (*A*) **258,** 1292, 90–100, Oct. 1960.

Many who have read von Karman's 1949 paper on an unsteady two-dimensional cavity flow [AMR **4** (1951), Rev. 292] have noted that there is no distinction between the case in which the body is accelerating in a liquid at rest and the case in which the body is held stationary and an accelerating flow streams past it. The present author makes this distinction and gives explicit solutions for both cases. Like Karman the author treats nonsteady cavity flows having a separable velocity potential of the form

$$\Phi(x, y, t) = U(t)\, f(x, y).$$

For these special flows he gives general formulas for generating a class of exact solutions in each case, notes certain reverse-flow properties possessed by these general solutions, and investigates steady cavity flows in a gravitational field. Some of the solutions in these three classes are carried out in detail.

B. R. Parkin, USA

5424. Jones, A. M., and Knudsen, J. G., Drag coefficients at low Reynolds numbers for flow past immersed bodies, *AIChE J.* **7,** 1, 20–25, Mar. 1961.

This investigation involved experimental determination of the drag coefficient as a function of Reynolds number and various geometric ratios for spheres, cylinders and flat plates at Reynolds number ranging from 0.01 to 10.

Drag coefficients were determined by measuring the force required to move those bodies vertically through two types of heavy duty gear oil; the equipment was first calibrated by measuring the drag on spheres.

The possible error in the force measurement approaches 20% but a number of velocities were investigated for each body and the data were analyzed by a least-squares method.

For all bodies studied the drag coefficient was inversely proportional to the Reynolds number; the data have an average deviation between 20% and 30% from the theoretical equation.

The diameter of the tank containing the viscous fluid had a very definite effect upon the drag coefficient of the various cylinders and flat plates studied, and authors give a curve to be used to predict drag coefficients for flat plates in perpendicular flow within ranges of parameters D_t/L and W/L.

L. Escande, France

5425. Wislicenus, G. F., Hydrodynamics and propulsion of submerged bodies, *ARS J.* **30,** 12, 1140–1148, Dec. 1960.

Before one spends money and effort on developing a particular vehicle to carry a given load at a desired speed it is well to know whether this carrier is the most efficient type for the speed and load. An excellent study for this purpose based upon the operating characteristics of a wide variety of carriers was presented in 1950 by Gabrielli and von Karman in "What price speed" [AMR 4 (1951); Rev. 2324]. Another important and useful help in this problem is given in present paper which deals with the drag-to-weight ratio of submerged bodies with brief considerations also given to surface planing craft. The author shows that, assuming a constant coefficient for frictional drag, the drag to buoyancy force for similar underwater bodies will vary with the square of the Froude number, $V(gl)^{-1/2}$. From this he shows that the drag of a buoyant body the size of a torpedo is greater than that of a hydrofoil or airfoil-supported craft at all useful speeds. For a 1000-ton vessel, the underwater propulsion develops less drag than airfoil or hydrofoil propulsion up to a speed of 33 knots, while a 64,000-ton craft at any foreseeable speed develops less drag as a submerged body than as a hydro- or airfoil-supported body.

In his considerations of machinery weight and efficiency, the author first considers machinery weight per unit of power to be constant, thus obtaining a ratio of machinery weight to vehicle weight that varies with $V^2(gd)^{-2}$. He then discusses the similarity considerations that cause machinery weight to increase with the cube of the linear dimensions while the power increases with the square, so that the final ratio of machinery weight to vehicle weight is found to vary with V^2g^{-1}. Thus the propulsion weight becomes increasingly more critical as the speed is increased. Propulsion plants that give high power per unit of weight tend to be inefficient. The use of thrust augmenters taking advantage of the boundary-layer energy may be desirable.

As the speed of waterborne bodies is increased, difficulties with cavitation can be expected, and travel with fully developed cavitation may be desirable.

Reviewer considers that paper presents interesting concepts which, although not developed sufficiently to serve as a basis for making commercial decisions on types of craft, can be useful guides to further more complete studies.

F. E. Reed, USA

5426. Kolf, R. C., and Reitmeyer, W. L., Vector aspects of dynamic similarity, *Proc. Amer. Soc. Civ. Engrs.* **87,** HY 2 (*J. Hydr. Div.*), 19–27, Mar. 1961.

Authors present a discussion of some laws of dynamic similarity in which Froude, Reynolds, and Euler numbers are contained (Euler number is here the reciprocal of the pressure coefficient).

As special cases authors mention the vortex chamber and hydraulic machinery, for which they introduce the Kolf number, a ratio between a circumferential and an axial velocity in a rotating fluid. This number is shown to be proportional to the reciprocal of the commonly used ratio between the discharge and the product of angular speed and third power of the impeller diameter.

A section is devoted to geometric similarity of open channel flows. Authors overlook the fact that in distorted model operated according to Froude law all the slopes are geometrically exaggerated, also the slopes of the water level both in longitudinal and in transversal direction (Eq. 36 is not valid), and that the roughness also determines herein the correct reproduction of flow patterns.

Reviewer is of the opinion that the treatment is oversimplified and therefore misleading. H. J. Schoemaker, Holland

Book—5427. Razvan, E., edited by, Experimental studies in hydraulics [Studii de hidraulica experimentala], Bucuresti, Institutal de Studii si Cercetari Hidrotehnice, 1959, 338 pp. (Paperbound)

5428. Prozdnikov, A. V., The principle of motion of a hydraulic engine with load accumulator operation (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Chern. Metallurgiya* no. 8, 71–80, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13648.

Calculation formulas are obtained by means of the equations for the motion of a piston for the determination of the characteristics of hydraulic engines with a drive from a load accumulator and hydraulic mechanisms in which the loadless running is effected by the action of the weight of the movable parts. The flow of liquid in the pipe conduit is assumed to be laminar. An analysis is carried out on the influence exerted by the parameters of the system on the work of the hydraulic mechanism. When the time-lag is small the calculations for the characteristics can be made by means of the nomogram supplied. V. A. Bashkin

Courtesy Referativnyi Zhurnal, USSR

Incompressible Flow

(See also Revs. 5178, 5181, 5414, 5415, 5419, 5421, 5424, 5447, 5479, 5482, 5485, 5493, 5508, 5511, 5520, 5529, 5530, 5532, 5604, 5684, 5685, 5686, 5687, 5688, 5777, 5785)

5429. Stewartson, K., Viscous flow past a quarter-infinite plate, *J. Aerospace Sci.* **28,** 1, 1–10, Jan. 1961.

A quarter-infinite plate is considered with its leading edge normal to and its side edge parallel to incident stream. Kinematic viscosity is assumed small. The Blasius problem is considered first and its limitations are shown. Then the perturbations to this solution are considered, to match the external potential flow solution. It is shown that the flow near the leading edge is simply related to that of a semi-infinite plate. The side edge gives rise to a shear flow. The effect of this edge is to change the skin-friction coefficient by a factor $0(\nu^{1/2} \log \nu^{-1})$.

A. W. Babister, Scotland

5430. Kanwal, R. P., Slow steady rotation of axially symmetric bodies in a viscous fluid, *J. Fluid Mech.* **10,** 1, 17–24, Feb. 1961.

The Stokes flow problem is considered for the case in which an axially symmetric body rotates uniformly about its axis of sym-

metry. Analytic solutions are presented for the heretofore unsolved cases of a spindle, a torus, a lens, and various special configurations of a lens. Formulas are derived for the angular velocity of the flow field and for the couple experienced by the body in each case.

From author's summary by A. C. Pipkin, USA

5431. Segel, L. A., Application of conformal mapping to viscous flow between moving circular cylinders, *Quart. Appl. Math.* **18,** 4, 335–353, Jan. 1961.

The fluid is incompressible. If outer cylinder is considered fixed, principal motions treated are slow rotation of slightly eccentric inner cylinder, and vibration of an inner cylinder about a slightly eccentric point. Mapping the given circular boundaries (of a cross section) into concentric circles enables one to solve for the stream function by a series. In the first problem, solution is carried far enough to afford an estimate for convergence. The torque on inner cylinder is computed. Angular velocity is considered constant or variable. Both problems are of general interest in connection with design of certain control mechanisms, and with experiments on Helium II.

From author's summary by R. Nardini, Italy

5432. Gorelik, L. V., On the connection between viscous friction forces and flow potential, *Soviet* Phys.-Tech. Phys. **5,** 6, 615–617, Dec. 1960. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* **30,** 6, 653–655 June 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

The dependence of the viscous friction force acting on a fluid flowing through a porous body on the gradient of the electric potential arising as a consequence of the appearance of a flow potential in laminar flow of a polar fluid through a porous body is obtained.

From author's summary

5433. Taylor, G. I., Deposition of a viscous fluid on a plane surface, *J. Fluid Mech.* **9,** 2, 218–224, Oct. 1960.

Author describes several ideal structures which will deliver fluid at a calculable rate. Calculations of thickness of deposits agree within wide limits of experimental error provided the effects of surface tension are neglected.

For a collection of vertical sliding parallel plates spaced a distance $2d$ apart, the total volume deposited on the horizontal plane per second for each pair is given by

$$Q = 1.085\,Ud^2$$

where U is velocity relative to the horizontal plate.

For a collection of semicircular grooves the volume deposited per unit length of run should be approximately $2a^2/\pi$, where a is the groove radius. Experimental values were within 8% of this prediction.

For a porous roller of radius R whose center moves with velocity U, the volume deposited per unit time is given as

$$Q = 2.96U(xR)^{1/2}$$

where x is a parameter length essentially the permeability divided by a length over which the fluid pressure acts. The thickness in this case is predicted to be

$$t = 1.48(XR)^{1/2}$$

Semiquantitative agreement between calculated and measured thickness is claimed for glycerine solutions. For the case of water, a relatively large surface tension and small viscosity is believed responsible for the lack of agreement between theory and observation.

W. R. Foster, USA

5434. Hama, F. R., and Nutant, J., Self-induced velocity on a curved vortex, *Physics of Fluids* **4,** 1, 28–32, Jan. 1961.

A brief, simple and interesting paper which shows that the self-induced velocity on a curved vortex is likely to be a maximum at the point of greatest curvature. This is done first by mathematical reasoning, secondly by experiment, using an electromagnetic analogy.

Reviewer finds the arguments and results convincing so long as the vortex core diameter is small compared with the radius of curvature. Apparently the vortex will deform until these are of the same order. Further experiments to follow this process and show more clearly the effects of core diameter would be interesting.

L. H. Tanner, England

5435. Pell, W. H., and Payne, L. E., The Stokes flow about a spindle, *Quart. Appl. Math.* **18,** 3, 257–262, Oct. 1960.

The problem of the Stokes flow about a spindle (an axisymmetric body), when the direction of the flow is parallel to the axis of the spindle, has been solved by using generalized axially symmetric potentials. It is shown that the Stokes flow around a sphere can be obtained as a special case from the solution given by the authors. Finally, an expression for the drag of the spindle is derived.

P. G. Bhuta, USA

5436. Bloom, M. H., On moderately separated viscous flows, *J. Aerospace Sci.* **28,** 4, 339–340 (Readers' Forum), Apr. 1961.

This note presents a relatively simple procedure for estimating viscous characteristics of a class of separated flows describable in terms of the boundary-layer approximation; in particular, with negligible pressure variations normal to the surface. The use of boundary-layer coordinates obviates assumptions concerning surface or flow geometry. Such flows, designated "moderately separated," may occur at flare-junctions, in shallow concavities, or in shock-boundary-layer interactions. For present purposes, the usually-increasing streamwise pressures are assumed to be prescribed, more complex coupling not being considered.

From author's summary

5437. Bretherton, F. P., The motion of long bubbles in tubes, *J. Fluid Mech.* **10,** 2, 166–188, Mar. 1961.

Theory and experiments are given on (1) bubble profile and excess of bubble speed over mean liquid speed, when tube radius is so small that gravity is unimportant; and (2) the rate of rise of bubbles in sealed vertical tubes due to gravity. Possible explanations for certain systematic divergences between theory and experiments are discussed.

A. G. Fabula, USA

5438. Okuda, S., The velocity distribution at the interface between two liquids, *J. Phys. Soc. Japan* **16,** 2, 324–338, Feb. 1961.

The velocity distribution was observed near the interface between two superimposed liquids having different densities, the heavier one confined in a hollow, Analysis based on a three-layer model (thin intermediate zone) gave a flow pattern in fairly good accordance with the observed one. The intermediate layer can exist in a stable state.

From author's summary by W. L. Sibbitt, USA

5439. Bennett, J. A. R., and Thornton, J. D., Data on the vertical flow of air-water mixtures in the annular and dispersed flow regions: Part 1, Preliminary study, *Trans. Inst. Chem. Engrs.* **39,** 2, 101–112, Apr. 1961.

This paper presents the results of a preliminary study of the vertical flow of air-water mixtures in the climbing-film and liquid-dispersed regions. Two-phase pressure-drop data were obtained using vertical glass and Perspex test sections having internal diameters of 1.36 and 1.25 in. respectively. Further determinations were also carried out using an annular test section formed from a 1.50 in. I.D. glass tube with a 1.0 in. polished stainless steel core fitted concentrically within it.

In the absence of a detailed knowledge of the flow dynamics of two-phase systems, the data were interpreted tentatively in terms of superficial two-phase friction factors by the method proposed by Govier, Radford, and Dunn. It must be emphasised however that further work is required before a generalized correlation can be developed which will satisfactorily take into account the effects of changes in flow pattern, size, geometry and surface characteristics of the flow channel and the physical properties of the system. From authors' summary

5440. Collier, J. G., and Hewitt, G. F., Data on the vertical flow of air-water mixtures in the annular and dispersed flow regions; Part 2, Film thickness and entrainment data and analysis of pressure drop measurements, *Trans. Inst. Chem. Engrs.* **39,** 2, 127–144, Apr. 1961.

Further data obtained by Bennett are presented, including measurements of film thickness and entrainment. Analyses carried out by the authors on these measurements, on the pressure drop data presented by Bennett and Thornton and on the interrelation between the two sets of measurements are also presented.

The knowledge of film thickness and film flow rate allows much more comprehensive analysis, and treatments based on the theories of Anderson and Mantzouranis and Calvert and Williams have been carried out. Complete data were obtained by Bennett for low liquid flow rates only and in this region large deviations from the theories occur. Some of these discrepancies are explained and the theories corrected, but large deviations still exist at low film thicknesses and can only be qualitatively accounted for.

The entrainment data have been presented in terms of the empirical correlation of Dukler and Wicks. Although good agreement with this correlation is observed for high entrainment, systematic deviations occur at values of low entrainment.

From author's summary

5441. Middleman, S., and Gavis, J., Expansion and contraction of capillary jets of Newtonian liquids, *Physics of Fluids* **4,** 3, 355–359, Mar. 1961.

Laminar jets of Newtonian liquids, when ejected from a capillary nozzle, contract or expand depending on conditions of ejection and on liquid properties. Ratio of final jet diameter to nozzle diameter is a function of Reynolds number, influenced slightly by the Weber number; at $Re < 16$ the jets expand, above 16 they contract. At $Re < 6$ expansion becomes independent of Re at a diameter ratio of 1.06, if the Weber number dependence is removed. At $Re > 150$ contraction becomes independent of Re at a diameter ratio of 0.87. Results are explained by momentum and energy equations for the motion; the terms in the equations leading to expansion express the relaxation of shear stress at the tube wall after the jet leaves the nozzle, and the transition from a parabolic to a constant flow velocity profile. Paper gives derivation of momentum and energy equations. In the experiments the jet was photographed in the light of a microflash unit giving an illumination of 2×10^{-6} sec duration. Velocity was measured by imparting to the nozzle a transverse vibration of known frequency, and measuring the wavelength of the resulting wave on the jet. This is a preliminary part of a larger investigation on the dynamics of viscous and viscoelastic liquid jets, on which further results and conclusions are to be published in the future.

K. J. DeJuhasz, USA

5442. Ueda, T., On the performance characteristics of steam ejectors, *Bull. JSME* **4,** 13, 124–131, Feb. 1961.

Steam ejectors can have three basic kinds of performance characteristics according to the outside conditions of ejector—driving stream pressure, back pressure of diffuser and flow rate of entrained fluid. From experimental studies on the flow state in ejectors, it has been shown that the three performance characteristics are closely connected with the types of the flow state, respectively, and the existing ranges of these characteristics can be simply expressed by the outside conditions of ejector. The results of experiment on the effects of the various dimensions of ejector are also presented. From author's summary

5443. Liepe, F., Efficiency of thin conical diffusers in swirling flows (in German), *Maschinenbautechnik* **9,** 8, 405–412, Aug. 1960.

The flow properties of a thin conical diffusor, into which swirling fluid is injected, are examined theoretically and experimentally. Particular attention is paid to the efficiency defined to be the ratio between the gain in pressure head to the loss in velocity head. The author arrives at some general conclusions about the effect the fluid properties at the inlet on the efficiency.

K. Stewartson, England

5444. Page, R. H., and Meyer, A. P., Hydraulic analog investigation of a plug nozzle, *ARS J.* **31,** 3, 447–448 (Tech. Notes), Mar. 1961.

5445. Bloom, M. H., Note on three-dimensional free-mixing, *J. Aerospace Sci.* **28,** 5, 430–431 (Readers' Forum), May 1961.

5446. Ghildyal, C. D., Unsteady motion of an infinite liquid due to the uniform rotation of a sphere, $r = a$, *Quart. Appl. Math.* **18,** 4, 396–399 (Notes), Jan. 1961.

A large body of fluid, initially at rest, is set into motion by a steady rotation of a solid sphere which begins at time $t = 0$. A solution is obtained for the transient and steady velocity distribution in the fluid. One of the stated conditions of the analysis is the existence of a particular form of external force acting within the fluid. The physical implications of such an external force are not discussed. E. M. Sparrow, USA

Book—5447. Goldstein, S., Lectures on fluid mechanics (Lectures in Applied Mathematics, Vol. 2; Proceedings of the Summer Seminar, Boulder, Colorado, 1957), New York, Interscience Publishers, Inc., 1960, xvi + 309 pp. $6.60.

This book is intended for mature mathematicians, and surveys problems arising in the field of fluid dynamics. Vector analysis has been used consistently and some knowledge of kinetic theory of gases, thermodynamics, relativistic electrodynamics, tensor analysis and transform theory is expected of the reader. The coverage in a book of such size is naturally not complete, and in several cases author has resorted to the study of particular topics, the choice being dependent on the importance of their physical application and mathematical interest. The approximations introduced to make the mathematical solutions tractable and the physical consequences of such actions are emphasized, but no detailed comparison of theoretical and experimental results is undertaken.

Chapter 1 deals with the kinematics of a moving fluid continuum, and Chapter 2 with the equations of motion and energy balance of a general fluid. Electrodynamic effects in an electrically conducting fluid are considered in Chapter 3. Chapter 4 is concerned with the fundamental equations for the flow of inviscid fluids, and includes a section on shock-wave propagation. A concise account of the basic equations of Newtonian fluid flow, leading to the Navier-Stokes equations, is given in Chapter 5, followed in Chapter 6 by some exact solutions of these equations for steady flow of incompressible and compressible viscous fluids. Boundary-layer theory for incompressible fluids is developed in Chapter 7, and includes the analysis of flow along a flat plate. In the same context a discussion appears in Chapter 8 on the difficulties of constructing an accurate asymptotic solution of the Navier-Stokes equations for flow past a flat plate at high Reynolds number. The effects of temperature variations on the theory of the

boundary-layer in gases are studied in Chapter 9. A very brief reference to the theories of turbulence and stability occurs in Chapter 10. The first part of Chapter 11 involves a discussion on the problems arising in the dynamics of inviscid fluids. Second part shows the use of the method of sources and transform theory in order to determine flow past slender bodies. Chapter 12 is a descriptive account of the factors to be considered when dealing with mixtures and high-temperature effects in gases. Chapter 13 is concerned with longitudinal wave motion in an ionized gas at high rarefaction. There are five appendices containing the definitions of certain basic concepts, and lists of formulas.

Special lectures by Professor J. M. Burgers illustrate some methods of approximation in magnetogasdynamics. First problem is that of penetration of a shock wave into the magnetic field due to a dipole set in a gas of high conductivity, and second problem deals with the electrical current in an ionized gas subjected simultaneously to electric and magnetic fields, and shows the need for a tensor conductivity coefficient.

Included also are a list of contents, book list, and author and subject indices. A large number of references appear in the text. The book is a useful summary of the basic theory of fluid dynamics, and should be a help to those who wish to study further in this field.

A few minor misprints were found in Chapter 1.

E. E. Jones, England

Compressible Flow (Continuum and Noncontinuum Flow)

(See also Revs. 5179, 5183, 5444, 5487, 5492, 5498, 5501, 5550, 5552, 5556, 5606, 5607, 5623, 5640, 5660, 5666, 5689, 5734)

5448. Kleiman, Ya. Z., On steady motion of a compressible multicomponent media (in Russian), *Izv. Akad. Nauk SSSR, Otd Tekh. Nauk, Mekh. Mash.* no. 1, 50–55, Jan./Feb. 1959.

Article studies the kinematic and dynamic characteristics of steady flows of mixtures of gases. Using strict analytical methods, it establishes subcritical, critical and supercritical regimes in such flows. One of the results is that when one of the two components of a mixture flows with a smaller velocity and also has a smaller dynamic pressure than the other, then the static pressure increases (downstream) in the case of the subcritical regime and decreases in the case of the supercritical regime. If, however, the component with the smaller velocity flows with a greater dynamic pressure, then the static pressure gradients are reversed in the subcritical and supercritical regimes.

The article analyzes several possible cases of mixture flows. It reaches interesting conclusions and puts forward useful ideas.

G. A. Tokaty and D. J. Huggett, England

5449. Tomilov, E. D., On a certain form of exact particular solutions of a plane, vortex free gas flow, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **24,** 3, 783–789, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Particular solution of Chaplygin's equation is obtained, in which the stream function is a polynomial in θ with the coefficients as functions of σ. The simplest of these are interpreted.

J. P. Guiraud, France

5450. Demele, F. A., and Brownson, J. J., Subsonic longitudinal aerodynamic characteristics of disks with elliptic cross sections and thickness-diameter ratios from 0.225 to 0.425, NASA TN D-788, 25 pp., Apr. 1961.

An investigation has been made to determine the effects of thickness on the longitudinal aerodynamic characteristics of a family of diskshaped bodies which might find application in the design of re-entry vehicles. The models had elliptic profiles which varied in maximum thickness from 0.225 to 0.425 diameter. The tests were conducted to maximum angles of attack of 25° over a range of Mach numbers from 0.25 to 0.90 at a Reynolds number of 3.3×10^6 and at Reynolds numbers to 16×10^6 at a Mach number of 0.25.

It was found that with the moment center located at 40 per cent of the diameter, the models were longitudinally unstable throughout the subsonic speed range. Increasing the thickness resulted in greater instability at low speeds but had little effect at high subsonic speeds. Increasing the Reynolds number from 3.3×10^6 to 16×10^6 resulted in large reductions in longitudinal instability and generally increased the lift-curve slope. Large increases in drag at lifting conditions accompanied increases in thickness. At low speeds the peak value of maximum lift-drag ratio, which was about 8 for a thickness-diameter ratio of 0.225, decreased to 4 as a result of increasing thickness-diameter ratio to 0.425.

From authors' summary

5451. Sleeman, W. C., Jr., Investigation at high subsonic speeds of the use of low auxiliary tail surfaces having dihedral to improve the longitudinal and directional stability of a T-tail model at high lift, NASA TN D-804, 23 pp., Apr. 1961.

An investigation of the use of low auxiliary horizontal-tail surfaces to alleviate the pitch-up tendency at high lift of an airplane configuration having a T-tail has been conducted in the Langley high-speed 7- by 10-ft tunnel. The basic model had a wing with an aspect ratio of 3, a taper ratio of 0.143, and an unswept 80-per cent chord line. The Mach number for most of the tests extended from 0.60 to 0.94 and the angle-of-attack range was from -2° to approximately 24° at the lowest test Mach number.

A preliminary study of a systematic series of auxiliary tails indicated that the pitch-up tendency at high lift encountered on the basic model could be greatly alleviated by use of a relatively small, very low-aspect-ratio auxiliary horizontal tail. This tail was located radially with respect to the fuselage center line with 30° negative dihedral and therefore provided a significant favorable increment to directional stability of the model throughout most of the test angle-of-attack range. From author's summary

5452. Stine, H. A., Wagoner, C. B., and Lugn, A. L., Jr., A study of the asymmetric transonic flow past a sharp leading edge, NASA TR R-66, 108 pp., 1960.

Experimentally determined features of the flow field about the leading edge of a 12° wedge with lower surface at an angle of 13° with respect to the stream and with nearly choked flow in the wind tunnel are compared with the calculated features corresponding to unbounded flow past the same body at a Mach number of exactly unity. In the theoretical calculation the leading-edge bubble pressure is so assumed that it satisfies the attachment condition given by Chapman and others [NACA TN 3869]. X-ray densitometer with narrow beam as well as broad beam was extensively used for density survey of the flow field. Detailed description of X-ray densitometer equipment, its operation, and density determination process is presented.

R. Kawamura, Japan

5453. Ovsyannikov, L. V., Group properties of Chaplygin's equations (in Russian), *Zh. Prikl. Mekh. Tekh. Fiz.* (*P.M.T.F.*) **1,** 3, 126–145, 1960.

Using the invariants approach of Laplace, the author develops general three-parameter expressions which may be used to approximate Chaplygin function $K(\sigma)$ appearing in Chaplygin's equation, $K(\sigma)\Psi_{\theta\theta} + \Psi_{\theta\theta} = 0$, of the hodograph method in gasdynamics.

Approximations in subsonic range of transformed speed variable σ lead to "Laplace-type" equations, while in transonic range "Tricomi-type" equations are obtained.

Reviewer feels that more detailed although not as general results were summarized by Chieh-Chien Chang in NACA TN 2582, Jan. 1952 [AMR 5(1952), Rev. 2888].

C. P. Kentzer, USA

5454. Romberg, G., Approximate calculation of the pressure coefficient on slender half bodies of revolution at zero incidence in sonic flow (in German), Dtsch. Versuchsanstalt Luftfahrt, Ber. 138, 47 pp., Dec. 1960.

The differential equation for the velocity potential ϕ in the transonic flow past axisymmetric bodies of revolution was reduced to tractable form by Oswatitsch and Keune [Proc. High Speed Conference, Polytechnic Institute, Brooklyn, N. Y. Jan. 1955; AMR 10(1957), Rev. 1160] who replaced the highest derivative of ϕ with respect to x (distance along the axis) by a suitable constant thereby obtaining a parabolic equation for ϕ. In this paper the approximation is generalized, the constant being replaced by the product of suitable functions of x and of y (distance from the axis). A general method of solving the reduced equation is described and applied to a particular body. It appears that the specific choice of function to replace the highest derivative of ϕ with respect to x has little effect on the drag coefficient.

No experimental evidence is adduced, which is unfortunate since the basic idea is mathematically unsound and its justification depends solely on experiment. K. Stewartson, England

5455. Nocilla, S., On the existence of steady, transonic flow past circular arc wing profiles (in Italian), *Atti Accad. Sci., Torino* **94**, 6, 796–822, 1959/60.

The direct problem for given airfoil shapes and Mach number at infinity is considered. Using the hodograph method and Tricomi's approximation the problem is reduced to the solution of two new hyperbolic parabolic equations. These two equations lead to a solution in form of series of functions whose convergence is examined. Finally the problem is reduced to an elliptic one with a partially parabolic boundary. In this last case there is no doubt concerning the existence of transonic steady flow.

From author's summary by W. Fiszdon, Poland

5456. Frankl', F. I., A new example of a plane-parallel transonic flow with a direct shock wave ending inside the flow (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Matematika* no. 2, 244–246, 1959; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13186.

It is shown that the solution of Tricomi's equation $\eta\Psi_{\theta\theta} + \Psi_{\eta\eta} = 0$ for the function of the current Ψ in canonical variables of the hodograph (θ,η) in the form

$$\Psi_v(\theta,\eta) = q^v f_v\left(\frac{\theta}{q}\right) \qquad \left(q = \sqrt{\theta^2 + \frac{4}{9}\eta^3}\right)$$

with $v = 2/3$ gives a transonic flow with a direct shock wave ending inside the flow. A well-defined expression is given for the function $\Psi_{2/3}$ in each of the regions into which the vicinity of the end of the shock wave breaks up with three characteristics emanating therefrom. The derived function $\Psi_{2/3}$ in the plane of the hodograph is single-valued when higher than the characteristic $\theta = 2/3(-\eta)^{3/2}$ while between the characteristics $\theta = \pm 2/3(-\eta)^{3/2}$ it has two signs for $\theta < 0$. The relation of the velocity vector to the coordinate of physical density in the vicinity of the end of the shock wave is single-valued. R. G. Barantsev

Courtesy Referativnyi Zhurnal, USSR

5457. Romeo, D. J., and Sterrett, J. R., Aerodynamic interaction effects ahead of a sonic jet exhausting perpendicularly from a flat plate into a Mach number 6 free stream, NASA TN D-743, 26 pp., Apr. 1961.

An investigation of the effects of the interaction ahead of a two-dimensional sonic jet exhausting perpendicularly into a Mach number 6 free stream from a flat-plate model has been conducted. The tests were made at an angle of attack of 0° at a Reynolds number per foot of approximately 6×10^6 and with conditions of both transitional and turbulent separation on the flat plate. The ratio of jet stagnation pressure to free-stream static pressure was varied from 8 to 460 and the jet slot width was varied from 0.001 to 0.05 inch. The force ratio (ratio of the normal force due to aerodynamic effect to the normal force due to reaction of jet), calculated ahead of the jet, was sizable and varied from 0.5 to 9. In general, the ratio increased with increasing pressure ratio and decreasing slot width. For the turbulent boundary-layer separation tests it was found that the first peak pressure and the chordwise pressure distribution of the separated boundary layer ahead of the jet were similar to those for a separation caused by a forward-facing step at the same test conditions. From authors' summary

5458. Stivers, L. S., Jr., and Levy, L. L., Jr., Effects of sting-support diameter on the base pressures of an elliptic cone at Mach numbers from 0.60 to 1.40, NASA TN D-354, 30 pp., Feb. 1961.

5459. Sirieix, M., Base pressure and turbulent mixing in plane supersonic flow (in French), *Rech. Aéro.* no. 78, 13–20, Sept./Oct. 1960.

An experimental investigation into the flow behind a step down is described, as a model for the flow round the rear of a body. In particular are considered (1) the effect of the boundary-layer thickness on the pressure distribution at the step and (2) the effect of injection into or suction from the dead water zone behind the step, for various Mach numbers at reattachment. The velocity profiles in the mixing zone between the main flow and the dead water zone are also measured. A comparison with Korst's theory [T. N. 392–2, University of Illinois] shows satisfactory agreement.

K. Stewartson, England

5460. Carafoli, E., and Mateescu, D., Supersonic flow around the cruciform wing-conical body system (in English), *Rev. Mécan. Appl.* **5**, 3, 301–312, 1960.

Herein is treated the supersonic linearized flow about a conical-body-wing system with an additional flat surface normal to the plane of the wing. The incidence of the body differs from that of the wing which in turn differs from that of the plate.

By means of Buseman's transformation the body cross section is transformed to a circle in the complex plane, the wing coincides with the real axis, and the plate cross section is reproduced on the imaginary axis. By further transformation the problem is reduced to one of a conical flow about a certain fictitious cruciform wing alone. K. A. Faymon, USA

5461. Ermolenko, S. D., and Vorob'ov, N. F., Agreement of tests on characteristic wings of finite span at supersonic velocity calculated by linear theory (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **30**, 131–138, 1960.

The aerodynamic data of three delta wings with subsonic, sonic and supersonic leading edges, measured in a supersonic wind tunnel at $M = 2$ are presented. The experimental results are compared with the linear theory developed by E. A. Krasil'shchikova (1952) for supersonic leading edges and by A. Gilles for subsonic leading edges [AMR 4(1951), Rev. 3005]. The measured lift coefficients are, in all three cases, approximately 20% smaller than those predicted theoretically. W. Wuest, Germany

5462. Shirokov, N. N., Retardation of supersonic flow in diffuser channels of wind tunnels (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. Mash.* no. 2, 19–24, 1959.

Experiments have been undertaken with an intermittent supersonic wind tunnel in the range $2.5 < M < 3.5$, having behind the test section a supersonic diffuser with adjustable walls. The in-

vestigations included measurement of static pressure along the center line of the diffuser and schlieren photos at different stations. The results are compared with a theoretical analysis for an ideal fluid and full agreement is found for the pressure distributions. Also the effects of boundary layer have been studied by measuring velocity profiles in the y, z-axis of the cross section at different stations x. W. Wuest, Germany

5463. Krasnov, N. F., The bottom resistance of bodies of rotation (in Russian), Nekotoryie Vopr. Mekh. (MVTU, **88**), Moscow, 1958, 95–102; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13229.

Some physical concepts are put forward connected with the emergence of bottom rarefaction beyond the body of revolution, both in cases of subsonic and of supersonic velocities. A formula is obtained on the basis of existing experimental data [Horner, Chapman, Perkins, Wick, "Questions of missile techn." Colln. of translations and reviews of international period. lit. no. 3, (21), 1954] for the determination of the bottom resistance in conditions of supersonic flow past of a missile. G. I. Bogomolov

Courtesy Referativnyi Zhurnal, USSR

5464. Ladyzhenskii, M. D., On gas flows with a high supersonic velocity, *Soviet Phys.–Doklady* **5,** 5, 944–947, Mar./Apr. 1961. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **134,** 2, 296–299, Sept. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

5465. Ehlers, F. E., On the lift, drag, and moment on a ring concentric to a cylindrical body in supersonic flow, *J. Aerospace Sci.* **28,** 2, 170–171 (Readers' Forum), Feb. 1961.

5466. Willett, J. E., Supersonic flow at the surface of a circular cone at angle of attack, *J. Aerospace Sci.* **27,** 12, 907–912, 920, Dec. 1960.

Formulas for the inviscid flow properties on the surface of a cone at angle of attack are derived for use in conjunction with the M. I. T. cone tables. These formulas are based upon an entropy distribution on the cone surface which is uniform and equal to that of the shocked fluid in the windward meridian plane. They predict values for the flow variables which may differ significantly from the corresponding values obtained directly from the cone tables. The differences in the magnitudes of the flow variables computed by the two methods tend to increase with increasing free-stream Mach number, cone angle and angle of attack.

From the author's summary by W. T. Snyder, USA

5467. Lun'kin, Yu. P., Variation of the parameters of a gas in connection with the nonequilibrium dissociation behind a shock wave, *Soviet Phys.–Tech. Phys.* **5,** 6, 585–589, Dec. 1960. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* **30,** 6, 622–626, June 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

An approximate procedure for the calculation of the nonequilibrium dissociation region behind a shock wave in a single diatomic gas is presented. Reviewer considers the approximations severe and questions the usefulness of the technique.

R. E. Duff, USA

5468. Enig, J. W., Stability criteria for numerical solutions of the normal and shock regions in unsteady two-dimensional cylindrical Lagrangian flow, U. S. Nav. Ord. Lab. Rep. 6726, 14 pp., Mar. 1960.

Paper presents mathematical derivation of stability conditions for numerical solution of axially symmetric time-dependent shock flow problems. The treatment is closely related to the method used by von Neumann and Richtmeyer for the corresponding one-dimensional problem. The flow equations are written in the Lagrangian form, whereas shocks are computed by means of the well-known pseudo-viscosity technique. Shock regions and normal regions are treated separately; in each of them a stability criterion is given. Verification in actual computation is mentioned.

E. Van Spiegel, Holland

5469. Zav'ialov, Iu. S., An approximate method of solving the problem of plane vortex gas flow, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24,** 2, 328–339, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author demonstrated in his earlier paper [*Doklady Akad. Nauk SSSR* **116,** no. 3] that, if $(1/v)\,(\partial^2 v/\partial p^2)$ is independent of ψ (v velocity, p pressure, ψ stream function), equation of vortex motion reduces to a linear equation. In this paper he points out that the above condition is approximately satisfied in adiabatic flow field with small entropy variation. The resulting linear equation of vortex motion with transformed stream function ψ^* as dependent variable and p and flow-direction angle θ as independent variables can be reduced to the potential-flow equation by replacing ψ^* by ψ and the coefficient $\lambda_0(p)$ by v. Transformation formula from p, θ-plane to physical one consists of a term similar to that of potential flow and another which contains vortex function. Thus there exists a potential flow corresponding to each vortex motion and vice versa. In supersonic case general solution to the linear equation is obtained using characteristic variables, and boundary-value problems for supersonic flows with and without shock are discussed.

R. Kawamura, Japan

5470. Lyakhov, G. M., Shock waves in multi-component media (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. Mash.* no. 1, 46–49, Jan./Feb. 1959.

The behavior of shock waves in nonhomogeneous media (e.g. emulsions, fogs, water with air bubbles, etc.) has been investigated theoretically and experimentally by several Russian authors. In the present paper, a three-component medium of very fine dispersion (solid and liquid particles in air) is considered and expressions for the velocity of sound and shock front are derived. Numerical examples are given for a mixture of water and quartz particles in air. W. Wuest, Germany

5471. Lyakhov, G. M., and Polyakova, N. I., Approximate method of analysis of shock waves and their interaction (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. Mash.* no. 2, 13–18, 1959.

A method for calculating the one-dimensional unsteady problem of shock wave propagations has been developed by stepwise approximation of the adiabate by straight lines and using Lagrangian coordinates. The method also includes reflection of shock waves at solid walls. W. Wuest, Germany

5472. Van Tuyl, A. H., Rational approximations formed from Chester's series for the body behind a given axially symmetric bow shock wave, *J. Aerospace Sci.* **28,** 2, 162–163 (Readers' Forum), Feb. 1961.

5473. Kuropatenko, V. F., A method of calculation for shock waves, *Soviet Phys.–Doklady* **5,** 4, 687–689, Jan./Feb. 1961. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **133,** 4, 771–772, Aug. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

5474. Muggia, A., Hypersonic nonsymmetrical flow close to the stagnation point of an airfoil with a nearly circular leading edge (in Italian), *Atti Accad. Sci., Torino* **94,** 6, 836–854, 1959/60.

Nonviscous constant density flow behind the shock wave is assumed. Using polar coordinates, the shape of the shock wave is expressed in form of a series and the solution is obtained by taking a corresponding series form for the flow function. Coefficients of this series are determined from the conditions at the shock wave.

The solution is obtained in terms of Bessel functions and for specific heat ratios close to one these are expanded in series. Relations between airfoil and shock-wave shapes are found and the velocity and pressure distributions in the vicinity of the stagnation point are obtained.

A particular solution for a symmetric airfoil at an angle of attack is given. W. Fiszdon, Poland

5475. Monaghan, R. J., Crabtree, L. F., and Woods, B. A., Features of hypersonic heat transfer, Advances in Aeronautical Sciences, Vol. 1 (Proc. of the First International Congress in the Aeronautical Sciences, Madrid, Sept. 8–13, 1958); Pergamon Press, 1959, 287–313.

This paper concerns the effects of dissociation on temperatures and heat transfer, both for bluff and for slender bodies and considers the equilibrium temperatures (aerodynamic heating balanced by radiation) that might be reached in hypersonic flight. Thermochemical equilibrium is assumed in all cases.

The stagnation temperature of a hypersonic flow can depend on pressure as well as on enthalpy (because of dissociation) and illustrations are given of the stagnation temperatures that would be achieved by various types of compression.

Heat-transfer rates to bluff bodies are taken from the work of Fay, Detra, Kemp and Riddell. For slender bodies, the "Couette flow" solution is modified to be applicable to a flat plate boundary layer, and the influence of atomic diffusion on energy profiles is shown.

Consideration of equilibrium temperatures indicates that slender shapes could be very suitable for hypersonic flight, provided leading edges and tips could be protected (e.g. by mass transfer cooling).

From authors' summary by G. M. Ketchum, USA

5476. Hartsell, C. W., Concerning real gas effects on hypersonic inlet performance, *J. Aerospace Sci.* **28,** 3, 253–255 (Readers' Forum), Mar. 1961.

5477. Friedlander, S. K., Particle impaction efficiencies for bodies in a free molecule flow, *ARS J.* **31,** 1, 96, 153–154, Jan. 1961.

Using particle fluxes based on Maxwellian velocity distributions the fraction of particles swept out by the body which strike the surface are evaluated for a sphere, cylinder, and ribbon. Such "efficiencies" decrease to unity with increasing molecular speed ratio. Application to study of atmospheric radioactive debris sampling is suggested. J. R. Baron, USA

5478. Swaim, R. L., On the feasibility of using aerodynamic control on vehicles operating in regions of slip flow and free-molecule flow, *J. Aerospace Sci.* **28,** 4, 349–350 (Readers' Forum), Apr. 1961.

5479. Antonovich, S. A., Calculations for jet pumps (ejectors) (in Russian), *Energomashinostroenie* no. 9, 8–13, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13366.

A method is described for calculating the transverse and longitudinal dimensions of ejectors with a gradually constricting inlet section and with a cylindrical mixing chamber. The proposed method for the calculations of the ejectors is based on the utilization of the empirical relation of the distribution of the axial velocities in the transverse section of the jet, and also on the use of one experimental constant (the coefficient for the structure of the jet) and comprehension of "the boundary layer of finite width." It is noted that with increase in the length of the chamber the losses in the outlet diffuser diminish but there is an increase in the losses due to friction in the mixing chamber of the ejector. Acting on these observations the author determines the optimum length for the mixing chamber of the ejector by means of a minimum expression, representing the sum-total of the loss of energy due to friction in the mixing chamber and the general loss of energy in the diffuser. The length of the mixing chamber determined in this way depends on the regime of working of the ejector. For one of the models of the ejector on a calculated regime of working a value of (L/d) opt = 6 was obtained. The experimental investigations made demonstrated the fact that the calculation data agree very satisfactorily with the results.

Yu. A. Lashkov
Courtesy Referativnyi Zhurnal, USSR

5480. Stefanovskii, B. S., The simulation of ejection apparatus (in Russian), *Nauchn. Dokladi Vyssh. Shkoly. Mash. i Priborostr.* no. 1, 75–86, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13367.

The possibilities are investigated of the simulation of ejection apparatus with the object of adaptation to a low pressure gas ejector with a cylindrical mixing chamber. Approximate modelling of ejection apparatus with sufficiently high precision was found possible provided the following conditions were met: (1) complete geometrical simulation of model and actual apparatus, (2) parity of the ejection coefficients; (3) parity of the product of the exponent of the adiabate by the square of the Mach number of the section of the nozzle of the high pressure gas; (4) parity of the relation of the specific gravity of the ejecting gas on the section of the nozzle to the specific gravity of the mixture of gases at the outlet to the mixing chamber. It was shown experimentally that the optimum length for the mixing chamber of the ejector depends on its geometry and coefficient of ejection. Ejectors with high-pressure nozzles of different geometrical design were examined. It was demonstrated that the adoption of nozzles designed as described enabled the length of the mixing chamber of the ejector to be appreciably shortened in some cases.

Yu. A. Lashkov
Courtesy Referativnyi Zhurnal, USSR

5481. Koldobskaya, T. G., Problem of nearly self-similar unsteady motion, *ARS J.* **30,** 9, 853–859 (Russian Suppl.), Sept. 1960.

Self-similar gas motion is defined analytically by means of a system of equations in which the number of independent variables can be reduced by a change of variables. Unsteady, nearly self-similar motion is analyzed by perturbing basic self-similar flow and linearizing the resulting equations. A transformation is used to make the new flow self-similar. The technique is discussed for nearly wedge-shaped and nearly conical bodies.

The condition of self-similar motion is valid only for a perfect gas with constant specific heats.

J. N. Aguirre, Argentina

Boundary Layer

(See also Revs: 5419, 5429, 5434, 5447, 5457, 5459, 5475, 5490, 5591, 5601, 5606, 5625, 5686)

5482. Gill, W. N., and Scher, M., A modification of the momentum transport hypothesis, *AIChE J.* **7,** 1, 61–63, Mar. 1961.

A modification of the Prandtl mixing length is assumed, which is of exponential character. The constants involved in the assumed expression are evaluated so that the model will yield results converging to the Hagen-Poiseuille equation at one extreme and give good agreement with existing data at the high Reynolds number range.

The generalized velocity distribution which is obtained is in excellent agreement with experimental results for flow between infinite flat plates. Similar results are shown for circular tubes.

The model is such as to require no division of the flow into separate regions as in previous models.

H. N. McManus, Jr. USA

5483. Ovchinnikov, O. N., The laminar boundary layer on a plate in an inhomogeneous flow, *Soviet Phys.-Tech. Phys.* **5,** 6, 590–601, Dec. 1960. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* **30,** 6, 627–638, June 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

Author treats the problem of an incompressible flow of constant vorticity passing a semi-infinite plate. Assuming the vorticity is small, a perturbation theme based on the square root of Reynolds number is employed for the solution of the stream function. The boundary conditions for various approximations are discussed, in particular, the first two approximations. These two approximations are, respectively, that of Blasius problem and that found by Li [*J. Aero. Sci.* **22**(1955), p. 651]. This result can be expected from physical intuition.

Using the same approach, the heat-transfer problem with Prandtl number being unity is similarly solved. Author also includes a case of Prandtl number equal to two; however, it is limited to a uniform incident flow (with zero vorticity).

L. N. Tao, USA

5484. Petukhov, I. V., A numerical solution of the laminar boundary-layer equation, *Soviet Phys.-Doklady* **5,** 3, 489–492, Nov./Dec. 1960. (Trnaslation of *Doklady Akad. Nauk SSSR (N.S.)* **132,** 2, 307–310, May 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

The incompressible-boundary-layer problem is approached as if it were an inviscid flow but with a different surface of the body, i.e., a displacement of the surface. The governing equation in terms of these fictitious velocity components is that of parabolic type. The methods of characteristic and successive approximations are then used to match the unknown displacement. No numerical illustration is given. L. N. Tao, USA

5485. Wan, K.-S., Some similar solutions for incompressible laminar boundary layer problems, AFOSR TN 59-1303 (Polyt. Inst. Brooklyn, Dept. Aero. Engng. Appl. Mech. Rep. 538), 28 pp., Dec. 1959.

The paper gives three types of similarity solutions:

1. Unsteady boundary-layer flow with the external irrotational flow inversely proportional to a linear function of time and varying linearly in the direction of the main flow.
2. Steady boundary-layer flow with external irrotational flow $u_0(1 + bx)^m$.
3. Interaction of the boundary layer with the external inviscid rotational flow for special cases for the external vorticity.

There is no mention in the references to the fundamental papers of W. Mangler, H. Schuch and T. Geis on similarity solutions of the boundary-layer equation. K. Pohlhausen, USA

5486. Watson, J., The two-dimensional laminar flow near the stagnation point of a cylinder which has an arbitrary transverse motion, *Quart. J. Mech. Appl. Math.* **12,** 2, 175–190, May 1959.

Exact solution of Navier-Stokes equations for two-dimensional flow normal to an infinite plate performing *arbitrary* transverse motions is derived.

M. B. Glauert's solution for boundary-layer growth on oscillating plates is generalized. Solutions are obtained by Laplace-transform techniques using series and asymptotic expansions respectively for the velocity in the boundary layer in small and large time interval motions.

For intermediate times an approximate "Pohlhausen-type" solution is given, valid for all times and sufficiently close to exact at extremes to warrant satisfactory results.

E. L. Houghton, England

5487. Tendeland, T., Nielsen, H. L., and Fohrman, M. J., The flow field over blunted flat plates and its effect on turbulent boundary-layer growth and heat transfer at a Mach number of 4.7, NASA TN D-689, 59 pp., Feb. 1961.

Surface pressure and local heating-rate distributions were measured on a flat plate with various cylindrical leading edges at a free-stream Reynolds number of 3.8×10^6 per foot. Predictions of static pressures and turbulent heat-transfer coefficients were in agreement with measured values. Impact and static pressure surveys in the flow field over the plate indicated an outward flow deflection that caused a displacement of the shock-wave asymptote of about 3°.

From authors' summary by J. V. Becker, USA

5488. Szablewski, W., Analysis of the measurement of turbulent boundary layers by means of wall relations (in German), *Ing.-Arch.* **29,** 4, 291–300, Aug. 1960.

In previous papers [AMR **8**(1955), Rev. 2078; **9**(1956), Rev. 1898; and **10**(1957), Rev. 2608], author developed formula for velocity distribution in turbulent boundary layers with pressure gradient based on Prandtl's mixing-length theory and compared it with experimental results of Nikuradse. In this paper comparison is made with experiments of Fage [R. & M. 1852 (1938)], Sandborn and Slogar [AMR **8**(1955), Rev. 2072] and Schubauer and Klebanoff [AMR **4**(1951), Rev. 352]. Good agreement is shown for the first two comparisons. R. C. Roberts, USA

5489. Bro, P., and Steinberg, S., Entrance effects in the high temperature heat transfer from dissociated gases, *ARS J.* **31,** 3, 375–376, 433 (Tech. Notes), Mar. 1961.

5490. Wrage, E., Development and application of a generalized series method for the calculation of compressible laminar boundary layers (in German), Dtsch. Versuchsanstalt Luftfahrt, Ber. 134, 94 pp., Nov. 1960.

This report provides the generalization of Goertler's transformation and series solution to the laminar boundary-layer equation to the case of compressible flow including the coupling between the momentum and energy equations. The results can be computed in terms of Goertler's universal momentum function and a similar set of universal functions that Wrage developed for incompressible laminar heat transfer.

This work provides a means of calculating, to any desired accuracy, the boundary-layer velocity and temperature distributions. However, this accuracy is obtained at the cost of some complexity. As may be expected the calculations agree with the earlier results that had been found for special cases.

E. E. Covert, USA

5491. Lapin, Yu. V., Friction and heat transfer in a compressible turbulent boundary layer in the presence of chemical reactions caused by the introduction of foreign material, *Soviet Phys.-Tech. Phys.* **5,** 10, 1162–1171, Apr. 1961. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* **30,** 10, 1227–1237, Oct. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

In this report the effects of chemical reaction (proceding at very fast rate) at a thin layer upon heat transfer and skin friction are studied. The solution is found by satisfying the boundary-layer equations above and below the reaction plane and joining the two solutions. The viscosity C_p and other properties are allowed to vary with temperature and concentration, subject to the assumption that the Lewis number is one.

The results show the well-known reduction of skin friction and heat transfer with increasing injection, and also illustrate, explicitly, the effects of variable properties. Numerical results require numerical interaction for each case.

E. E. Covert, USA

5492. Laufer, J., and Vrebalovich, T., Stability and transition of a supersonic laminar boundary layer on an insulated flat plate, *J. Fluid Mech.* **9,** 2, 257–299, Oct. 1960.

Paper presents results of theoretical and experimental investigation of instability of small disturbances in boundary layer, which provides the triggering mechanism for transition from laminar to turbulent state. Self-excited oscillations have been discovered experimentally in a supersonic boundary layer along a flat plate. Detailed study of their behavior was made and compared with theory. Differences between stability of incompressible boundary layer and that of compressible one were brought into focus. Experimental equipment description includes hot-wire carriage, disturbance generator giving frequency range from 5000 to 50,000 c/s without affecting normal boundary-layer growth and flow field, wind-tunnel turbulence reduction method, wave analyzers. Graphs show growth of supersonic boundary layer, variation of disturbance amplitude, etc. Neutral stability curves, mass flow, total temperature and pressure fluctuation in boundary layer were also obtained. It was found that boundary layer acts as a frequency selective amplifier, depending on local Reynolds number. The stability limits of a perturbation of given frequency depend on the Reynolds number based on local thickness and are independent of Mach number. Main effect of compressibility manifests itself in increase in wave velocity with Mach number, hence disturbances possessing the same dimensionless amplification coefficient as in incompressible flow have less time to grow in amplitude, and adiabatic compressible boundary layer is more stable than incompressible one. Rough estimation of transition Reynolds number is made. Its value increases as Mach number increases in compressible flow range. P. Bielkowicz, USA

5493. Kirchgassner, K., Instability of flow between two rotary cylinders—Taylor vortices for arbitrary annuli (in German) *ZAMP* **12,** 1, 14–30, Jan. 1961.

Taylor's instability of a viscous incompressible flow between two concentric cylinders is here extended to the more general case of finite gap width between the cylinders. The flow pattern of the cellular circulations is found numerically as an eigenvalue problem. Comparison of the calculation results with the measurements by Donelly agree within 1%.

H. A. Einstein, USA

5494. Feldman, S., Stabilization of Taylor instability by a shearing flow, *Physics of Fluids* **4,** 3, 385–386 (Letters to the Editor), Mar. 1961.

5495. Yoshizawa, Y., The effect of a chemical reaction on the shear flow over a plate, *Trans. Japan Soc. Aero. Space Sci.* **3,** 4, 21–29, 1960.

In this paper, a four-component Couette flow with a carbon monoxide and oxygen reaction in the gas is discussed. The carbon monoxide is injected at the colder wall. The analysis is necessarily based upon several simplifying assumptions. It is likely that the assumption of constant properties has some influence in the detailed behavior of the flow, but not in the gross effect. It should be noted that the results, which are obtained by numerical integration, show the ordinary influence of injection, i.e., the chemical reaction has no influence upon the shear. Since the reaction governs the temperature and thus the value of the properties, it would seem that this result may be a direct consequence of the assumption of constant properties.

E. E. Covert, USA

5496. Kestin, J., Maeder, P. F., and Wang, H. E., On boundary layers associated with oscillating streams, *Appl. Scient. Res.* (*A*) **10,** 1, 1–22, 1961.

Paper describes the effects which are produced in laminar boundary layers by the presence of oscillations in the free stream. These are two in number. First, the external oscillations induce oscillations in the boundary layer itself; the phases of the oscillations at different distances from the wall in the boundary layer are shifted with respect to each other and to the forcing oscillation. This is a purely viscous effect. Secondly, the oscillation occurs about a different mean profile from the steady-state profile which would correspond to the average external velocity. The latter effect is equivalent to a secondary flow. It is lost in a mathematical analysis in which the inertia terms are neglected and depends, therefore, on an interplay between the inertia and viscous forces.

The paper also contains a series solution for the skin-friction coefficient on and rate of heat transfer from a flat plate in a uniform stream on which there is superimposed a harmonic oscillation progressing with a velocity equal to the mean velocity of flow.

From authors' summary by H. J. Schoemaker, Holland

5497. Mattioli, E., Shearing stress in the flow along a flat plate (in Italian), *Aerotecnica* **39,** 6, 290–294, Dec. 1959.

Report is given on the results of measurements made, in a wind tunnel, along a flat plate with zero pressure gradient. There are set forth certain considerations on the turbulent boundary layer based on the laws of similitude. It is shown that the series expansion for the shear stress in the vicinity of the plate is dominated by the term containing the cube of the distance from the wall. From author's summary by G. W. Housner, USA

Turbulence

(See Revs. 5491, 5492, 5497, 5632, 5739, 5740, 5773, 5795)

Aerodynamics

(See also Revs. 5183, 5449, 5452, 5453, 5460, 5475, 5477, 5486, 5492, 5529, 5547, 5550, 5551, 5557, 5564, 5648, 5685, 5700, 5705)

5498. Legendre, R., Simple method of calculating a slender wing (in French), *Rech. Aéro.* no. 78, 7–11, Sept./Oct. 1960.

Method of calculating airfoil suitable for flight Mach numbers from 0 to 2.0 is developed within the general framework of the R. T. Jones and G. N. Ward theories of flow about slender bodies. For reasons justified in some detail, ordinary Joukowsky condition usually applied at trailing edge of subsonic airfoil is here applied over entire wing. A suitable distribution of potential over wing surface is first assumed; then, by use of a mathematical artifice, a difficult integration is avoided and the corresponding wing shape is determined by a process of differentiation. Choice of potential distribution is naturally restricted to some extent, but enough freedom exists to select values which facilitate practical construction, and method is sufficiently concise to permit several comparative calculations. Validity of method has apparently not been checked against practice, since no experimental results are given, but supersonic wing designers might well consider possibilities of the method. C. W. Smith, USA

5499. Mantle, P. J., On the rolling motion of low-aspect-ratio delta wings, *J. Aerospace Sci.* **28,** 5, 427–428 (Readers' Forum), May 1961.

5500. Salaun, P., Forces and moments acting on an airfoil in calm air (in French), *Rech. Aéro.* no. 74, 49–54, Jan./Feb. 1960.

5501. Sinnott, C. S., On the prediction of mixed subsonic/supersonic pressure distributions, *J. Aerospace Sci.* **27,** 10, 767–778, Oct. 1960.

Problem of transonic flow over airfoils is treated in semi-empirical manner. Flow is considered in three parts: supersonic flow upstream of shock, shock pressure rise, and subsonic flow downstream of shock. Wind-tunnel data are used in formulating procedure for determining pressure distributions. Procedure is outlined by an example. Author discusses theoretical methods and shows how to improve them by utilizing his method. Physical mechanism and limitations are discussed.

R. W. Van Aken, USA

5502. Vogler, R. D., Effects of various arrangements of slotted and round jet exits on the lift and pitching-moment characteristics of a rectangular-base model at zero forward speed, NASA TN D-660, 25 pp., Feb. 1961.

An investigation was made at the Langley Research Center to determine some of the effects of slotted and round jet exits on the lift and pitching-moment characteristics of a rectangular-planform model at zero forward speed. Pressure ratios and weight rates of flow are included in the data. Pressure ratios varied from 1.04 to 1.50. The ratio of jet-exit area to base area varied from 0.03 to 0.10. The model base was 8 by 20 inches.

From author's summary

5503. Cook, G. E., The aerodynamic drag of near earth satellites, Aero. Res. Counc. Lond. Curr. Pap. 523, 27 pp. + figs., 1960.

Free-molecule drag coefficients for several simple shapes are calculated for the classical cases of diffuse and specular reflection. The drag coefficient for an inclined circular cylinder with arbitrary molecular speed ratio is obtained by integration; the results given for flat plate, sphere, and cone closely follow the work of Stalder and Zurick [AMR **4**(1951), Rev. 4613] and Schaaf and Chambré [AMR **12**(1959), Rev. 3979]. Numerical calculations for several artificial satellites are discussed. The author suggests that high-speed molecules reflect from a surface in random directions with complete energy accomodation. However, reviewer believes that partial energy accomodation such as indicated by Hurlbut [Rand Corp. R-339 (1959)] and Hartnett [Rand Corp. RM-2585 (1960)] could significantly increase the drag coefficient.

R. H. Edsall, USA

5504. Gainer, T. G., Low-speed investigation on the effects of large wing-sideslip angles on the aerodynamic characteristics of two arrow-wing-fuselage arrangements, NASA TN D-656, 41 pp., Feb. 1961.

An investigation has been made of two methods proposed to reduce the high sinking speeds and improve the landing characteristics of low-aspect-ratio hypersonic airplanes by placing the wing at large angles of sideslip to increase its effective aspect ratio. The models investigated had conical fuselages and arrow wings, with a leading-edge sweepback of 77.4°, an aspect ratio of 1.23, and a 4-percent-thick straight-wedge section. For one model the wing was pivoted on the fuselage to angles of wing sideslip from 0° to 90°. For the other model, the wing was fixed to the fuselage and the wing and fuselage were yawed together to sideslip angles from 0° to 90°.

From author's summary

5505. Martellucci, A., An investigation of a low-drag auxilliary body utilizing favorable interference, *J. Aero/Space Sci.* **26,** 8, 538–540 (Readers' Forum), Aug. 1959.

5506. Richards, P. F., The estimation of tail loading due to elevator-induced pitching maneuvers—a proposal for an approximate analytical method for airworthiness calculations: Part 1, Qualitative discussion; Part 2, Quantitative discussion; Part 3, Appendices, *Aircr. Engng.* **32,** 371, 2–15, Jan. 1960; **32,** 372, 37–51, Feb. 1960; **32,** 373, 77–83, Mar. 1960.

Paper considers airworthiness design tail loads and associated torques due to elevator-induced pitching maneuvres. Analytical methods are presented for response calculations for checked and unchecked maneuvres. The effects of autopilot feed-back failure and aircraft size, weight and c.g. position are discussed, together with those of forward speed and altitude.

D. W. Holder, England

5507. Etkin, B., A simple method for the analogue computation of the mean-square response of airplanes to atmospheric turbulence, Univ. Toronto, Inst. Aerophys. Rep. 32, 11 pp., Jan. 1960.

Dealing with the problem of the response of an airplane to random atmospheric turbulence the mean-square response is often the only quantity desired. Paper presents an elegant method for obtaining this quantity in a direct way without calculation of frequency response and output power spectra. The method is based on the simple fact that the square of the modulus of the amplitude spectrum of the exponential function $A e^{-\gamma t}$ is a good representation of the power spectral density of atmospheric turbulence. The response of a linear system to such an exponential input can be used for determining its mean-square response to atmospheric turbulence. The constants A and γ depend on the intensity of turbulence and the ratio of airplane size to scale of turbulence. Presented method is well-suited to analog computation.

E. Van Spiegel, Holland

5508. Ustinov, M. D., Investigation of the structure of a spiral vortex sheet in the vicinity of its free end (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27,** 45–53, 1960.

Author assumes ideal, incompressible, unsteady two-dimensional flow, vortex-free outside vortex sheets and lines. Circulation around a body with sharp trailing edge is determined by Joukowsky's law for the case of steady flow, when vortex sheet shed from trailing edge extends to infinity. In unsteady flow dynamic interaction between the body and vortex sheet induces continuous changes of the sheet represented in plane flow as a line whose free end curls, forming a spiral. Functions of general character are established complying with the conditions on vortex line. Rejection of small terms enabled author to find velocity of any vortex element sufficiently close to free end of vortex line.

P. Bielkowicz, USA

5509. Kopal, Z., Aerodynamic effects in planetary atmospheres, *Aerospace Engng.* **19,** 12, 10–11, Dec. 1960.

Vibration and Wave Motion in Fluids

(See also Revs. 5179, 5328, 5481, 5492, 5496, 5734, 5739, 5740, 5741, 5774)

5510. Maruo, H., The drift of a body floating on waves, *J. Ship Res.* **4,** 3, 1–10, Dec. 1960.

In 1924, K. Suyehiro reported measurements of the drift forces acting on models that are broadside to waves. These forces reach a maximum when the heaving frequency of the model coincides with the wave frequency.

The problem has been studied theoretically by Watanabe, 1938, and by Havelock, 1942. The present author, working with a cir-

cular cylinder, a sphere and other simple solids, and applying more complete considerations, shows that the drifting force is related to both the reflection of the wave and the phase lag of the oscillation, a question left unanswered by the previous investigators.

F. E. Reed, USA

5511. Tsao, S., Waves on the surface of a uniformly vortical fluid (in Russian), *Zh. Prikl. Mekh. Tekh. Fiz.* **2**, 15-21, 1960.

It is shown here that even in the absence of gravitation and capillarity the uniformly vortical fluid has a restoring force which can serve as the reason for the formation of surface waves due to disturbances. In particular the problem of propagation of a disturbance on the surface of a uniformly vortical fluid of constant depth is considered. The appropriate boundary-value problem is

$$\Delta\varphi = 0 \text{ [a] } \varphi_y = 0 \text{ for } y = -b \qquad \varphi_t - b\psi = 0 \text{ for } y = 0$$

$$\text{[b] } \varphi(x,0,0) = l(x) \qquad \zeta(x,0) = f(x)$$

where b is the depth, b a constant vortex intensity, ψ the conjugate of φ, $l(x)$ the ratio of pressure impulse at the initial time and the density, $f(x)$ the initial surface position.

The problem with conditions [a] admits a known solution to which Fourier methods are applied to solve the complete problem. Contrary to the cases of gravitational and capillary waves it is shown that in the linear approximation no waves can arise due solely to a disturbance of the surface ($l(x) = 0$). A special case for $l(x) \neq 0$, $f(x) = 0$ is analyzed and expressions for the surface $\zeta(x,t)$ are given for the cases $b = \infty$ and $b = \text{const}$ $|x| \gg b$.

For the former the surface vibrations are periodic and the wave energy is preserved, while for the latter it is shown that the waves propagate only in one direction and that the smaller the depth the faster the amplitude decreases. Furthermore the impulse disturbance is propagated with a velocity equal to the group velocity for the limiting case $b = 0$.

D. Boyanovitch, USA

5512. Smyslov, V. V., Calculations for standing waves in open quiet flows (in Russian), *Naucbn. Dokladi Vyssb. Skboly. Stroitel'stvo* no. 1, 219-222, 1958; *Ref. Zb. Mekb.* no. 11. 1959, Rev. 13491.

Paper deals with a general discussion on standing waves in an open flow based on methods used in hydraulics. The equation for the specific energy of the section of the flow, with account being taken of the distortion of the jets, is presented in the form of

$$\theta = b + \frac{\alpha v^2}{2g} + k\frac{v^2}{g}b \qquad [1]$$

where the last term represents the supplementary pressure due to the action of centrifugal forces caused by the distortion of the jets. For a channel with a straight sloping bottom

$$k = \frac{d^2b}{ds^2}\frac{1}{x} \qquad [2]$$

where x is some coefficient. After substitution of [2], Eq. [1] is integrated once. The integral obtained is investigated in detail, numerical caluclations are given which show that for Froude numbers less than 0.1 waves do not appear at all in the liquid, in the majority of cases.

Yu. P. Ivanilov

Courtesy Referativnyi Zhurnal, USSR

5513. Ursell, F., Steady wave patterns on a non-uniform steady fluid flow, *J. Fluid Mech.* **9**, 3, 333-346, Nov. 1960.

A concentrated surface pressure is imposed on the free surface of a steady slightly nonuniform flow. Paper is concerned with calculation of resulting pattern of free surface waves. Review of simpler problem of waves on a uniform flow shows that Kelvin's ship-wave pattern is the result. This is clearly explained by Lamb ["Hydrodynamics," 1932, section 256]. From this solution a series of assumptions regarding the geometry of the pattern are derived and applied to the case given in the title. These are the familiar techniques in ray tracing. A further assumption which is physically logical is then made so that the complete pattern of wave crests can be deduced. Method is applied to so-called symmetric waves on a thin film with surface tension which is either uniform or radially expanding. The equations for the crests are shown to approximate those of Taylor [*Proc. Roy. Soc. Lond.* (*A*) **253**, 289-321, 1959; AMR **13**(1960), Rev. 5297]. These are thus confirmed by the experiments.

Reviewer believes paper will be of particular engineering significance in that solutions of problems of wave motion previously considered intractable will now be feasible. Method will not be so simple when a finite body is considered.

W. D. Baines, Canada

5514. Laitone, E. V., The second approximation to cnoidal and solitary waves, *J. Fluid Mech.* **9**, 3, 430-444, Nov. 1960.

Paper considers higher-order solutions of the finite-amplitude long water waves which are propagated without change of shape in shallow water. A successive approximation method is used which consists of a power series development in terms of a dimensionless parameter which is related to the transformations that are found necessary in order to yield the classical nonlinear shallow-water equations from the zero-order terms in this small perturbation series. It is shown that retention of the first-order terms yields solutions for the solitary wave and cnoidal waves which have been obtained previously. The second approximations to the solitary and cnoidal waves are shown to depend on some fourth-order terms in the expansion. These higher-order terms give a solution in which the pressure is not hydrostatic and the vertical velocity and acceleration is not small. These are the primary differences from the more simple solutions. Second approximation indicates that the maximum elevation of any finite wave is 8/11 of the depth below the trough. This indicates that the limiting total height of a solitary wave is 1.727 times the undisturbed water depth. This value is in much better agreement with experimental evidence than values given by previous analyses.

W. D. Baines, Canada

5515. Ursell, F., Dean, R. G., and Yu, Y. S., Forced small-amplitude water waves: a comparison of theory and experiment, *J. Fluid Mech.* **7**, 1, 33-52, Jan. 1960.

Work done previously on small-amplitude water waves has resulted in confirmation of inviscid flow theory as regards particle orbit, frequency and velocity measurement. However, others have observed that measured wave heights were as much as 30% less than computed values. Authors attempt to shed light on this discrepancy by appropriate mathematical analysis and carefully conducted experiments for case of piston-type wavemaker. Customary theory neglects reflection from beach, attenuation, higher harmonics and nonlinear effects. Authors present results of such theory for both paddle and piston wavemakers, then discuss effects which such complicating factors have on problem.

Experiments using piston wavemaker were conducted in channel of 100-ft length, 2½-ft width, 3-ft depth and beach slope 1:15. Hook and point gage was used to measure wave heights. First series was devoted to waves of small steepness (H/L from 0.002 to 0.03). Average values of measured wave heights were 3.4% below theoretical values. Second series was concerned with large steepness waves (H/L from 0.045 to 0.048). Measured heights averaged 10% below theoretical. In both series, experimental error was about 3%. Though data were corrected for reflection, effect was not appreciable; viscous attenuation also appeared negligible.

Authors consider that leakage past wavemaker and finite amplitude effects were main reasons for difference between theory and experiment. They can present no explanation for much larger dis-

crepancies observed previously on experiments using paddle wavemaker; they suggest neglect of reflection, leakage past wavemaker, non-simple harmonic wavemaker as possible explanations. Authors believe analysis is valid for both piston and paddle wavemakers for small-amplitude waves. R. B. Banks, Thailand

5516. Gun'ko, F. G., Regarding the hydraulic jump and the connected depths in three-dimensional conditions (in Russian), *Izv. Vses. Nauk-i. In-ta Gidrotekhn.* **59**, 100–119, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13605.

A critical review is given of the studies on the hydraulic jump in three-dimensional conditions with examination of the case where the river-bed suddenly widens. Experimental data of the author are furnished to show the succession of changes of form in the linkage of the upper and lower waters when the depth of the lower water changes and also when there is a sudden widening of the flow. In the light of the author's data the form of transition of a turbulent flow into a quiet flow may differ, as due to lines of increased level, an oblique jump, a flow of the water mass of the lower water on to the turbulent flow, a shock-wave, an ordinary or ideal jump with a rectilinear or curvolinear front. The transition from a turbulent flow to a quiet flow may take place on a portion of large length or on a comparatively short portion, when it may happen that the "quiet" regime in practice may frequently be quite unsuitable because of the large velocities and the instability of the flow.

T. N. Astaficha
Courtesy Referativnyi Zhurnal, USSR

5517. Naudascher, E., Contribution to the study of vibration exciting forces on simultaneously over and under flowing weirs (in German), *Tech. Mitt. Krupp* **17**, 5, 230–275, Dec. 1959.

A limited number of authors have dealt with vibrations in gates when over-topped by spilling water or when under-flowed by a jet of water. The author deals with combined over-topping and underflowing of a gate. This problem is basically one which has to be solved experimentally, as there is no known method to calculate the varying hydraulic forces acting on the gate. Different gate shapes and sills were tested for one weir. The author goes beyond this experimental research and formulates some general views on the problem of vibrations in gates.

Part 1 is a general introduction, part 2 summarizes the laws of similarity (Laws of Froude and Strouhal) to be used for forces and frequencies. The first model used for the tests is described in part 3. Vertical forces acting on the gates and the frequencies were measured experimentally. More fundamental and experimental work on a second model is summarized in parts 4 and 5, with the purpose to come closer to separating average static forces and varying dynamic forces, mainly responsible for vibrations. The inertia of measuring instruments is taken into acount for determining the rapidly varying dynamic forces. Results are tabulated and discussed in the last part. The analysis is based mainly on different combinations of classical linear equations of the second order. A detailed bibliography shows a good grasp of the subject.

Reviewer estimates the paper to be very valuable, especially as literature on this subject is rather scarce.

C. Jaeger, England

5518. Ivanilov, Iu. P., On the stability of plane-parallel flow of a viscous fluid ove. an inclined bottom, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24**, 2, 549–552, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author applied small perturbations of long wavelengths to the stream-function equations of the problem. He discusses the solution of the resulting ordinary differential equation of the fourth order and derives the stability conditions of the flow.

K. Pohlhausen, USA

5519. Rumiantsev, B. N., On waves generated on the surface of an incompressible fluid by a shock wave, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24**, 2, 344–356, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Motion of an inviscid incompressible fluid resulting from shock wave pressure applied to its surface is treated, neglecting the effect of gravity. Boundary condition is given on the original fluid surface on which pressure distribution is assumed to be known from shock-wave or blast-wave theory ignoring the displacement of the surface. Laplace equation for the velocity potential of the fluid motion is solved and self-similar solutions are obtained for cases of two-dimensional plane shock with constant or variable pressure behind it, cylindrical blast wave and spherical blast wave. In each case velocity and displacement of the fluid surface are calculated. R. Kawamura, Japan

5520. Filippov, I. G., Solution of the problem of the motion of a vortex under the surface of a fluid, for Froude numbers near unity, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24**, 3, 698–716, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

For Froude number near unity but larger than unity, an approximate solution is found which reduces to a solitary wave when the strength of the vortex approaches zero. The problem is formulated by mapping the wave surface and bottom on a unit strip. The precise solution is governed by a system of nonlinear integral equations through the use of a Green's function. The existence of an exact solution which reduces to a solitary wave in the limiting case is also shown. It is remarked that some minor misprints exist in the paper. W. H. Chu, USA

5521. Snegirev, I. A., Investigation of the surface shock wave of water (in Russian), Nauchn. Soobshch. Tashkentsk. In-ta Inzh. Zh.-d. Transp. no. 8, 24 pp., 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13621.

Paper gives an account of the experimental investigation of the surface shock wave of water beyond the spillway construction, equipped with a ledge and beyond the damper. Relations are proposed for the determination of the boundaries of formation of the surface shock wave beyond the spillway structures with a vertical ledge and beyond the energy dampers in the form of aprons and discontinuous thresholds in conditions governing a three-dimensional problem. The boundary is determined between the plane and the spatial problems of the interlinkage of the upper and the lower waters of the surface regime type. Recommendations are given for the determination of the velocities at the surface and near the bottom and also of the pulsational components of the velocity of the flow on the portion comprising the linkage of the upper and lower waters. In addition, the effect is estimated of the damping of the energy of the flow by the bottom and the surface shock waves.

T. N. Astaficheva
Courtesy Referativnyi Zhurnal, USSR

5522. Ippen, A. T., Toebes, G. H., and Eagleson, P. S., The hydroelastic behavior of flat plates as influenced by trailing edge geometry, Mass. Inst. Technol., Hydrodynamics Lab., Dept. Civ. Sanitary Engng. TR 36 (Contract no. Nonr-1841(21)), 105 pp., Apr. 1960.

Report is concerned with a review of current thought on the hydroelastic vibration of thin plates at zero angle of attack in a stream and with the analysis of the results of an experimental study of this phenomenon at the Hydrodynamics Laboratory, M.I.T. It is pointed out that in the present state of knowledge there does not exist an adequate correlation of trailing-edge geometry and wake structure with the vibrational response of thin plates. From a number of flat plates which were placed in the water tunnel, determinations of the amplitude and frequency spectra of the vibration were made. Plates were mounted with freedom to move only

about a vertical axis included in the plate. The torsional motion of the plate is at first calculated according to the usual representation as a second-order spring-mass system with a forcing moment postulated on the basis of a varying circulation-type lift which is generated by the action of the Karman vortex system in the wake. Authors then proceed to criticize this model because it provides no dependence on Reynolds number and imply that the phenomenon is nonlinear in character by invoking the fact that instabilities have been observed in the case of circular cylinders. This reasoning is difficult to follow. A nonlinear equation is then derived using both viscous and inviscid concepts dealing with pitching wing sections. It is possible to discuss this nonlinear equation in qualitative terms.

Analysis of the data for two sets of plates having thickness of 1/8 in. and 1/4 in. with a variety of trailing-edge shapes shows that the amplitude of vibration is strongly dependent on trailing-edge configuration and that the vibration is definitely associated with the formation of vortices. Plots of the data presented in terms of the double amplitude in fraction of plate thickness divided by a factor proportional to U^2/S (U being the stream speed and S the Strouhal number) as a function of the ratio of response frequency to natural frequency show fairly strong resemblance to the response characteristics of a nonlinear system with a soft spring. This is taken as justification for the need of a nonlinear analysis. Two practical recommendations are made: (1) trailing edges of blade-like objects should be well streamlined to negligible thickness to allow the separating shear layers to annihilate one another; (2) if, for structural reasons, a thick edge must be used, a groove should be cut in the mid-line at the trailing edge to provide the least stabilization of the inherently unstable shear layers to promote three-dimensionality in the fluid motion. While this work necessarily leaves unanswered questions, it is highly recommended to those interested in the "singing" of propeller blades and other related hydroelastic phenomena.

J. P. Breslin, USA

5523. Movsesyan, L. A., Nonstationary flow of compressible gas in long pipelines (in Russian), *Inzbener. Fiz. Zb.* **4**, 1, 22–26, Jan. 1961. •

An approximate theoretical method is given for calculating the possibility of accumulating gas at the end portion of long pipelines where, due to its practical use, the flow is essentially nonstationary. The problem is reduced to the heat-conduction equation, by assuming one-dimensional isothermal gas flow, neglecting inertia forces. The solution is found using the Laplace transformation method.

W. Fiszdon, Poland

5524. Riley, J. D., and Trembath, N. W., Sloshing of liquids in spherical tanks, *J. Aerospace Sci.* **28**, 3, 245–246 (Readers' Forum), Mar. 1961.

5525. Becker, E., Ship waves as an example of wave propagation in an anisotropic dispersive media (in German), *ZAMM* **41**, 1/2, 26–31, Jan./Feb. 1961.

Geometry of waves in a dispersive anisotropic medium is discussed and the general laws derived. Relationships for wave crests in wave number space are discussed in detail. Results are applied to the moving point pressure disturbance on the surface of an infinite liquid. Solution is the same as the classical Kelvin ship-wave problem.

W. D. Baines, Canada

5526. Kiaman, R. Ya., Some characteristic features of the action on the hull of a ship of three-dimensional waves several times shorter than the length of the ship (in Russian), *Sudostroenie* no. 11, 9–13, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13520.

Together with the investigation of the strength of a river vessel, study was carried out of its reaction to three-dimensional wind waves for the case when the vessel is on a course parallel to the direction of propagation of the waves. A table is compiled for the values of the apparent periods of the waves, for the periods of the basic current of the natural vibrations of the ships, for the periods of changes of supplementary stresses in the hull, and so on. On the basis of full-scale tests of some types of river craft the explanation is furnished that the changes in supplementary stresses in the hull of the vessel appear to be of a transient nature but that in calculation the upper limit of these stresses can be determined by means of a tensogram. When computing the stability of vessels on a straight course it is proposed to consider the wave arrangement as following a chess-board pattern; when calculating the upper limit of the stresses the following points have to be taken into account: the damping of the waves below the ship's bottom, the dynamic character of the action of the wave load and the flexibility of the ship's hull. In this case the forms of the elastic lines of the hulls of ships, examined as beams, coincide with the forms found in the full-scale tests: this is, actually, a double-jointed vibration in the form of a single half-wave. The usual method of calculation by statistical analysis without taking into account the damping of the waves under the hull of the ship leads to a multi-jointed form of deflection of the line of the hull of the ship.

V. S. Voitsenya

Courtesy Referativnyi Zhurnal, USSR

Book—5527. Swainger, K., Analysis of deformation: Vol. 4, Waves and vibrations, New York, Macmillan Company, 1959, xxvii + 370 pp. $15.

5528. Sretenskii, L. N., and Sekerzh-Zen'kovich, Ya. N., The Cauchy-Poisson problem for waves of finite amplitude, *Soviet Phys.-Doklady* **5**, 4, 677–678, Jan./Feb. 1961. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **133**, 3, 544–545, July 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

Fluid Machinery

(See also Revs. 5213, 5290, 5321, 5425, 5443, 5659, 5784)

5529. Betz, E. A., Progress in the calculation of flow through cascades (in German), *Z. Flugwiss.* **9**, 1, 2–15, Jan. 1961.

Author presents the results of mathematical and experimental investigations of the flow through radial cascades such as in centrifugal pumps and compressors, and straight cascades as in turbines and axial flow compressors. The general objective of the work is to present a comprehensive presentation of the progress made at Gottingen in the last 5 years in the calculation of the flow of incompressible fluids through cascades.

The first section considers the radial flow in rotors and presents the results obtained by conformal representation for various numbers of radial segments, and the calculated results for circular cascades with finite radius ratios and three types of flow: (a) vortex flow of strength Γ, (b) source flow with the value E,, (c) rotation with the angular velocity ω. A sketch is given of a test apparatus which comprises a belt running over two pulleys which produce a shearing flow over a flat plate inside the belt, simulating the shearing flow in radial rotors. Pictures of the flow pattern are shown.

The second section considers straight cascades with slightly cambered profiles. This case has been handled by various researchers, by use of singularities, particularly a series of vortices. This method is specially useful for determining the form of the mean camber line for a given pressure distribution. To determine the pressure distribution for a given profile the author presents a new linear theory for airfoil cascades by which it is easy

to determine the pressure distribution for thin cascades. The expressions are simple, and the results quite accurate; as shown by curves giving the results by this and a more accurate method presented later. A method is also presented for use with thick profiles, i.e. thickness ratios greater than 20%.

For highly cambered thin cascade profiles and highly cambered thick profiles, mathematical methods are presented for determining the velocity distribution. The author then develops another method to determine the pressure distribution for a given profile by use of an integral equation. The difference in the new method is that the disappearance of the velocity inside the profile contour is made a condition. The resulting equations are solved by use of an IBM 650 or 704 computer. The results of such computations are compared with measured results and very good agreement is reached, as shown by the curves reproduced.

This method presents a useful advance in the art of cascade computation, but is apparently limited to incompressible flows. A useful list of references is included, and the paper as a whole is an excellent review of cascade computation methods.

A. O. White, USA

5530. Soundranayagam, S., Approximate estimation of the passage vorticity in the secondary flow behind a cascade, *J. Roy. Aero. Soc.* **64,** 598, 635–638 (Tech. Notes), Oct. 1960.

Paper provides rapid approximate method of computing time for particle to traverse lower and upper surface of an airfoil in both accelerating and diffusing cascades. Relationship of secondary vorticity to pitch/cord ratio, stagger angle, and deflection is discussed and qualitatively demonstrated. Comparison of particle traverse time as computed by this method with time obtained by Squire and Winter method shows variations from zero to fifteen per cent, depending on geometry. Reviewer believes method is a useful tool within limitations expressed in paper.

J. T. Hamrick, USA

5531. Lieblein, S., Incidence and deviation-angle correlations for compressor cascades, *ASME Trans.* **82** D (*J. Basic Engng.*), 3, 575–587, Sept. 1960.

This correlation is for the minimum loss point obtained from constant air inlet angle tests and covers NACA 65 and British C series and double circular arc blades. Aerodynamic arguments are given for selecting the correlation parameters. The deviation rule is a generalization of Carter's and the incidence correlation follows similar lines. Design can be performed directly; iteration is required for performance calculation.

This is a useful correlation over most of the range; the limitations are covered in the discussion.

D. V. Foster, USA

5532. Bauer, A. B., Vortex shedding from thin flat plates parallel to the free stream, *J. Aerospace Sci.* **28,** 4, 340–341 (Readers' Forum), Apr. 1961.

5533. Gretsov, N. A., The hydraulic energetic characteristics of the suction tubes of pumps (in Russian), *Naucbn. Zap. Mosk. In-ta Inzb. Vodn. Kb-va* **20,** 144–157, 1958; *Ref. Zb. Mekb.* no. 11, 1959, Rev. 13588.

The efficiency (K.p.d.) is investigated of propeller-driven vertical and vertical-centrifugal pumps connected to the supply by means of curved suction tubes. Author looks upon the suction tube as a component part of the pump and determines the efficiency of this feed tube. Graphs are furnished to show the changes of efficiency in the feed tube in relation to the coefficient of high-speed action of the pump when the suction tube exhibits different hydraulic characteristics. The experimental check was carried out both under laboratory conditions and in actual tests on a screw-driven pump unit of type VP-250. The results of the laboratory and full-scale experiments were practically the same at Reynolds figures above 150,000–200,000. Data are given for the measurements of the turbulence of the flow in the suction tube.

M. F. Gubin
Courtesy Referativnyi Zhurnal, USSR

5534. Dorfman, L. A., and Grishchuk, S. V., A study of turbine stages with foliar directing blades (in Russian), *Energomashinostroenie* no. 12, 35–37, 1958; *Ref. Zb. Mekb.* no. 11, 1959, Rev. 13388.

Results are given of comparative tests carried out in air of the natural stages of steam turbines with solid cut blades and with stamped leaf-shaped blades in the jet apparatus. With short blades the efficiency (k.p.d.) of the stage with leaf-shaped directing blades was 6% lower than the efficiency of the stage with solid directing blades. This difference is explained by the fact that there is an increase in the profile losses in the leaf-shaped blades because of the noticeable diffusion portion on the spine of these profiles, at the point of a sharp change in the curvature of the profile, and an increase in the secondary losses because of the large gradient of velocities transverse to the duct. The original leaf-shaped profile was improved, which enabled the efficiency of the stage to be raised by 2% owing to a reduction in the profile losses; however attempts to reduce the end losses failed. A comparative investigation of long twisted blades showed that the difference in the adiabatic efficiency of the stages with solid directing blades and with leaf-shaped directing blades only amounted to 0.014. It would appear that with short cylindrical blades the use of leaf-shaped profiles is expedient. In the case of long twisted blades the use of leaf-shaped blades does not result in an appreciable lowering of the efficiency of the stage, as against their technological good points and their cheapness of manufacture. Calculations showed that for turbines with a power of Mwatts a changeover to leaf-shaped blades is justified on technical-economic grounds, the commencing height suggested being 150 mm.

V. Kh. Abiants
Courtesy Referativnyi Zhurnal, USSR

5535. Ellis, G. O., Crossover systems between the stages of centrifugal compressors, *ASME Trans.* **82** D (*J. Basic Engng.*), 1, 155–168, Mar. 1960.

Two principles are put forth governing design of transition systems. These principles are based on results from a discussion of simple elbows, as used in air duct systems, channels, etc. Conditions for design and dimensioning of crossover vanes with respect to minimal losses are derived mathematically. Experimental comparison with normally built model shows considerable decrease in crossover losses.

Use of proposed crossover vanes certainly improves performance of compressor operating under design conditions, but in some cases implies higher sensibility to changes of flow rate and load.

B. Regenscheit, Germany

5536. Carter, A. D. S., Turner, R. C., Sparkes, D. W., and Burrows, R. A., The design and testing of an axial-flow compressor having different blade profiles in each stage, Aero. Res. Counc. Lond. Rep. Mem. 3183, 23 pp., 1960.

A discussion of the requirements of the different stages is followed by design details of a compressor having in each stage the best suited profile. Test results lead to the conclusion that such a compressor has several advantages over one using the same profile throughout: good surge line, high part-load efficiency, wide characteristic at constant speed, possibly high efficiency at high

flow, high peak efficiency and good reliability. A disadvantage is the possibility of a lower surge pressure ratio at the design speed than a compressor with high load blade sections throughout.

From authors' summary by N. H. Johannesen, England

5537. Gretsov, N. A., Hydraulic resistance of rectilinear axial compressor suction tubes in pumps pumping water from tanks of large dimensions (in Russian), *Nauchn. Zap. Mosk. In-ta Inzh. Vodn. Kh-va* **20**, 158–164, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13589.

Paper deals with the subject of determining the losses in a straight axis compressor suction pipe of a pump. The losses are computed as the sum of the losses at the inlet end of the frictional losses along the length of the tube, the magnitude of each of these forms of loss being found on the basis of the geometrical dimensions of the tube and the degree of roughness of its walls. Results are given of the experimental verification of the formula being recommended, carried out in laboratory conditions on an atmospheric model. The difference between the experimental data and the results of calculations using the formula was between 2–3%. Graphs are given which reduce the burden of the calculation processes by the recommended method, and also a simplified formula the use of which results in an error of the order of 6 to 8%.

M. F. Gubin

Courtesy Referativnyi Zhurnal, USSR

5538. Barlit, V. V., Selection of edges for the blade of the working wheel of a radial-axial hydroturbine (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Energetika* no. 12, 110–117, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13643.

An examination is made of the possibility of improving the characteristics of radial-axial hydroturbines by suitable selection of the form of the inlet and outlet edges of the working wheel. The edges of the blades should not be radial in order to avoid inlet and outlet losses caused by vortex formation. Recommendations are given for the rational selection of the form of the edges and a method is described for the determination of the magnitude of the angles to which the edges of the blades of the working wheel have to be bent back. Results are given of a comparative, experimental investigation of working wheels types F320(I) and F320(II) with radial and nonradial edges to the blades. It was shown that wheels with nonradial edges to the blades have high energetic and cavitation qualities.

B. S. Dorogov

Courtesy Referativnyi Zhurnal, USSR

5539. Gongwer, C. A., Some aspects of underwater jet propulsion systems, *ARS J.* **30**, 12, 1148–1151, Dec. 1960.

For moderate speeds (less than 90 knots) of underwater vehicles, propellers turned by conventional underwater engines are superior in efficiency and range to other methods of propulsion. At higher speeds they have inadequate power and jet engines must be used.

The Hydropulse, an intermittent pulsing device using automatically operating reed valves, gives a fuel economy comparable to that of a rotating power plant but its high pressure surges, low percentage of working time and its proneness to external cavitation make it an unsatisfactory drive. Hydroducts, i.e. hydraulic ramjets, and hydroturbo jets are only briefly discussed. Liquid rockets are unsuitable for deep running because of limitations in chamber pressure, but solid rockets are claimed to be the most suitable propellants for high speeds. Graphs showing the speeds where cavitation starts as related to depth and to fineness ratio and a table of limiting steady underwater speeds for rocket-propelled missiles are presented.

F. E. Reed, USA

Flow and Flight Test Techniques and Measurements

(See also Revs. 5411, 5452, 5492, 5650, 5702)

5540. Maytin, I. L., Development of a variable reluctance velocity meter, *Proc. Amer. Soc. Civ. Engrs.* **87**, HY 1 (*J. Hyd. Div.*), 95–102, Jan. 1961.

Paper describes a miniature propeller-type meter which may be used with any gas or liquid. A sprocket on the propeller shaft causes variations in the reluctance to the magnetic flux radiating from a pole, and this causes a voltage to be induced in a coil. The amplified voltage is fed into a frequency meter. Prototype velocity meter was suitable for speed range 0.15 to 5 fps, but principle may be used at much higher speeds.

N. H. Johannesen, England

5541. Hooper, L. J., Effects of brine dispersion in the Allen salt-velocity method, *ASME Trans.* **83** A (*J. Engng. Power*), 2, 194–205, Apr. 1961.

This paper presents information concerning the effect of brine dispersion on the Allen salt-velocity method of measuring flow. The data are presented from a variety of sources, theory, laboratory investigation, and field tests. Theory and tests show that brine injected into a conduit disperses as the square root of the distance traveled. As a result of this relationship, salt-velocity curves occupy a smaller percentage of the passage time as the test length increases. This results in smaller test errors for long test sections. Also indicated in this paper are the results of further tests which show the minimum limits for length of test sections with equipment commonly used.

From author's summary

5542. Bujdoso, E., and Aladar, I., Measurement of flow velocity by radioactive isotopes (in Hungarian), *Meres Es Automat.* **9**, 2, 49–52, 1961.

5543. Gabashvili, T. I., A rotating vane of small inertia for measuring instantaneous velocities in flow (in Russian), *Trudi Gruz. Politekhn. In-ta* no. 3, 44–53, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13812.

The choice of a hydrometric rotating vane for the measurement of instantaneous velocities in flows of liquid is substantiated. The advantages of the given apparatus are pointed out: simplicity, reliability and the possibilities for using it in natural conditions. The construction is described of a four-bladed rotating vane with an ebonite body. The vane wheel is made of plexiglass. The contact device located on the same axis as the vane wheel enables six impulses to be received for each revolution of the vane wheel. The diameter of the vane wheel is 55 mm, the dimensions of the body 20 × 100 mm, the length of the vane with the vane wheel 126 mm. The current feed of the apparatus is effected by means of a generator of the type 3G-10 with a voltage of 900 Hertz for the elimination of electrolysis in the contacts. The recording of the signals was carried out on an oscillograph of type MPO-2. Calibration showed that the starting speed of the vane was 1.2 cm/sec with a range of stable performance for velocities between 2.55–90 cm/sec. The apparatus is reliable in operation, simple to assemble, does not change its characteristics when periodically dismantled and reacts rapidly to changes in velocity of the flow.

L. A. Gus'kov

Courtesy Referativnyi Zhurnal, USSR

5544. Szewalski, R., The critical pressure ratio for a series of orifices discharging steam or gas and its influence on the flow rate of the system (in Polish), *Arch. Budown Maszyn* **6**, 3, 349–361, 1959.

5545. Bouyer, R., Application of optical method based on contrast of phases for the study of flow of gases (in French), *Publ. Scient. Tecb. Min. Air, France* no. 361, 144 pp., 1960.

Paper describes attempts at quantitative use of the phase contrast method in investigating gas flows. Author shows that photometric measurements can relate unambiguously the photographic density of the image to the phase changes produced by the object, provided these do not exceed $\pi/2$. Reviewer believes that the sensitivity of the method also restricts its usefulness as, in practice, it would be very difficult to eliminate the effects of optical imperfections and of extraneous disturbances such as convection currents.

Paper also contains a lengthy appendix on computations of lenses. H. K. Zienkiewicz, England

5546. Clutter, D. W., and Smith, A. M. O., Flow visualization by electrolysis of water, *Aerospace Engng.* **20,** 1, 24–27, 74, Jan. 1961.

5547. Chang, P. K., Laminar separation of flow around symmetrical struts at zero angle of attack, *J. Franklin Inst.* **270,** 5, 382–396, Nov. 1960.

The flow separation on wind-tunnel models is observed by blowing talcum dust into the wake. If the model has been previously covered with a layer of lubricating oil, the powder will deposit on the oil as far upstream as the wake will carry it. The upstream limit of the dust deposit lies within the range of previous theoretical and empirical predictions. The method is extremely easy to apply and is little time-consuming.

H. A. Einstein, USA

5548. Hickey, D. H., Tolhurst, W. H., Jr., and Aoyagi, K., Investigation of the longitudinal characteristics of a large-scale jet transport model equipped with controllable thrust reversers, NASA TN D–786, 48 pp., Mar. 1961.

The model had a 35° sweptback wing of aspect ratio 7 and four pylon-mounted jet engines. The major portion of the study was directed at the use of partial thrust reversal for control of thrust during the landing approach. Analysis of the data indicates that, although the large amounts of thrust reversal cause an adverse effect on longitudinal characteristics, small amounts of reversal will give adequate thrust control during the landing approach without compromising longitudinal characteristics.

From authors' summary

5549. Mishkovich, I. M., Model tests of twin-duct, conical exhausters (in Russian), *Trudi Rostovsk. In-ta Inzb. Zb.-d. Transp.* no. 21, 233–250, 1958; *Ref. Zb. Mekb.* no. 4, 1959, Rev. 3703.

The results of model tests of single and twin-duct, conical exhausters with cold air are applied to a quantitative comparison of their characteristics. The experiments were made with circular, single-aperture and quadruple aperture cones, with a common discharge, for both models. In these tests, the models were geometrically similar, and the Mach numbers of the flows were likewise similar. No similarity of the Reynolds numbers was attempted. The test results show a considerable advantage of the twin-duct type of conical exhausters over the single-duct type.

I. S. Simonov

Courtesy Referativnyi Zhurnal, USSR

5550. Tirumalesa, D., and Satyanarayana, B., An experimental study of the interference properties of a slotted wall test-section at transonic speeds, *J. Aero. Soc. India* **12,** 4, 71–85, Nov. 1960.

Using half-model technique, pressure distributions over a 12 per cent thick circular arc airfoil were measured in a transonic test section with longitudinal slots for various values of open area ratio, model-chord to tunnel-height ratio, and Mach numbers. Assuming results of ONERA publication no. 65 can be considered as free flight results, differences in pressure distributions are analyzed in various ways. It is shown that for Mach numbers near 1, interference cannot be attributed to blockage only (i.e. correction on free-stream Mach number). Experimental chordwise interference corrections are derived and discussed. Comparisons with theoretical predictions are presented. H. Bergh, Holland

5551. Kelly, T. C., Transonic wind-tunnel investigation of the static longitudinal aerodynamic characteristics of several configurations of the Scout vehicle and of a number of related models, NASA TN D–794, 69 pp., May 1961.

Results have been obtained in the Langley 8-ft transonic pressure tunnel at Mach numbers from 0.40 to 1.20 for several configurations of the Scout vehicle and for a number of related models. Tests extended over an angle-of-attack range from about −10° to 10° at a Reynolds number per foot of about 3.8×10^6.

Results indicated that for an early version of the Scout vehicle, a change in second-stage transition-flare half-angle from 5.2° to 8.2° had negligible effects on normal-force and pitch characteristics but caused a slight increase in the transonic drag rise.

Tests of various configurations of a 1/15-scale model of the four-stage Scout vehicle indicated that the addition of various protuberances increased the axial force noticeably and caused a slight forward movement in center-of-pressure location. The addition of low-aspect-ratio fins on the second-stage transition flare caused slight general increases in normal-force-curve slope, pitching-moment-curve slope, and axial force and moved the center of pressure forward by about 2 to 5 per cent of the body length.

Results of tests of various configurations of a 1/10-scale model of a three-stage version of the Scout vehicle indicated that the addition of an afterbody flare to the fin-off configuration caused sizable increases in normal-force-curve slope and pitching-moment-curve slope, whereas addition of the same flare to the fin-on configuration had negligible effects.

From author's summary

5552. Loving, D. L., A wind-tunnel investigation of a transonic-transport configuration utilizing drag-reducing devices at Mach numbers from 0.20 to 1.03, NASA TN D–636, 117 pp., Mar. 1961.

The static longitudinal stability and control, and lateral characteristics of a transonic-transport model, incorporating recent drag-reducing devices, have been measured in the Langley 8-foot transonic pressure tunnel. Modifications to the model for reducing the drag were forward fuselage additions and special wing bodies. Other components and changes investigated included an empennage, a wing-tip body, wing fences, wing trailing-edge flaps, horizontal-tail settings, and wing dihedral angle. The investigation was made at angles of attack from −5° to 15.4°, sideslip angle of −5°, and Reynolds numbers from 0.5×10^6 to 1.9×10^6 based on the wing mean aerodynamic chord.

From author's summary

5553. Reid, C. F., Jr., and Wrestler, C. G., Jr., An investigation of a device to oscillate a wind-tunnel airstream, NASA TN D–739, 29 pp., Apr. 1961.

Measurements were made of the magnitude and phase relationship of an airstream oscillation generated in a wind-tunnel test section at low speeds in air and at Mach numbers to 0.80 in Freon 12, over a Reynolds number range of 1.78×10^6 to 3.82×10^6 per foot, and at frequencies to 20 cps. Tests also were made of the frequency response of a 60° delta semispan wing with a conically cambered leading edge to illustrate how the system may be applied.

From authors' summary

5554. Cornette, E. S., Wind-tunnel investigation of the effects of wing bodies, fences, flaps, and a fuselage addition on the wing buffet response of a transonic-transport model, NASA TN D-637, 65 pp., Apr. 1961.

5555. Smetana, F. O., Studies in the heating of a supersonic gas stream by a radio frequency discharge, AFOSR TN 60-648 (Univ. So. Calif. Engng. Center Rep. 56-214), 88 pp., July 1960.

Detailed discussion of use of RF discharge to heat a supersonic gas stream, principally as a method of raising stagnation enthalpy to correspond to hypersonic flight in the atmosphere. Unlike dc arc method, RF discharge is stable and uniform, and energy losses and cooling problems can be reduced. Report considers difficulties of putting the electrical energy into the gas stream, the choice of nozzle material, effect of discharge on nozzle aerodynamics, and ways in which ionization energy can be converted into heat.

Ideas were tested experimentally in Univ. of Calif. Low Density Wind Tunnel using frequency of 13.65 mc. Gases were argon, nitrogen and C_4F_8, used separately or in mixture. Teflon was found to be satisfactory nozzle material. Experiments suggest that RF discharge into supersonic stream is a more efficient way of heating gas than dc discharge upstream of throat and also causes less contamination. Equipment and shielding problems however are more difficult and costly to resolve. The RF discharge produces some variation in nozzle flow, generally reducing Mach number and encouraging flow separation. It is important that discharge-produced plasma should decay before reaching model; decay time can be decreased by increasing operating pressure and adding small amounts of contaminants which react chemically with atomic nitrogen. E. W. E. Rogers, England

5556. Keynton, R. J., and Fichter, Ann B., Investigation of the aerodynamic characteristics of two preliminary designs of Scout research vehicle at Mach numbers from 1.77 to 4.65, NASA TN D-821, 60 pp., Apr. 1961.

An investigation was conducted in the Langley Unitary Plan wind tunnel to determine the aerodynamic characteristics of two preliminary designs of the Scout research vehicle, which is a four-stage solid-fuel guided-rocket system. The first model was a complete four-stage model and was tested with two nose sections, two interstage flares, and two sets of trapezoidal fins with tip controls. A second model, consisting of the upper three stages of another design of the Scout research vehicle, was tested with two flares and a cylindrical body extension.

From authors' summary

5557. Lin, S.-C., and Fyfe, W. I., Low-density shock tube for chemical kinetics studies, *Physics of Fluids* **4,** 2, 238-249, Feb. 1961.

Description of preliminary investigation to develop low-density shock tubes. Reason for studying low densities (10^{-3} atmospheres) is that with high-temperature shock tubes operating at ordinary densities many interesting relaxation phenomena are inaccessible because of very fast specific rates involved. Paper describes design and development problems and shows that, because of pronounced curvature and tilt of shock surface, care must be taken in interpretation of data. Preliminary results are presented on dissociation and ionization rates, as well as visible radiation profile, behind strong normal shocks in air ($12 < M < 22$) at low densities. W. F. Davis, USA

5558. McFadden, N. M., Vomaske, R. F., and Heinle, D. R., Flight investigation using variable-stability airplanes of minimum stability requirements for high-speed, high-altitude vehicles, NASA TN D-779, 50 pp., Apr. 1961.

The ability of pilots to operate aircraft possessing a wide range of longitudinal dynamic response characteristics has been studied using variable-stability airplanes. Particular emphasis was placed on operation at negative static margins, resulting in the determination of minimum levels of stability and damping required for adequate control. Brief tests of the limits of controllability in the lateral-directional mode were also made.

From authors' summary

5559. Larras, J., and Claria, A., Wind tunnel research on relative wave and wind action (in French), *Houille Blanche* **15,** 6, 674-677, Nov. 1960.

5560. Schultz, M. P., Wind-tunnel test to determine wind loads on a 1:128 scale model of the AO 143 (T5 tanker) vessel, David W. Taylor Mod. Bas. Rep. 1468 (Aero. Rep. 996), 6 pp. + figs., Nov. 1960.

5561. Payne, H. E., III, Carter, F. R., and Harrison, W. J., The Navy's flying wind tunnel, *Aero/Space Engng.* **20,** 3, 18-19, 50-53, 56, 58-61, Mar. 1961.

Thermodynamics

(See also Revs. 5373, 5495, 5557, 5583, 5598, 5614, 5730)

5562. Uhlhorn, U., Statistical mechanical approach to non-equilibrium thermodynamics (in English), *Ark. Fysik* **17,** 3/4, 343-360, 1960.

Using a Hilbert space treatment of a stochastic process, the Onsager reciprocal relations are derived assuming time reversal symmetry but avoiding phenomenological macroscopic laws relating fluxes and gradients arising due to fluctuations. Arguments used are independent of whether quantum or classical mechanics is used in a microscopic description of the system. No new results are obtained, the purpose of the paper being to derive known relations using fewer postulates.

E. L. Knuth, USA

5563. Usmanov, A. G., and Berezhnoi, A. I., Investigation of molecular and thermal diffusion by the similarity method (in Russian), Konvektivnyi i Luchistyi Teploobmen, Moscow, Izdatel'stvo Akad. Nauk SSSR, 1960, 188-204.

In order to extend range of available data on molecular and thermal diffusion in gases a generalized equation is derived relating the mass flux ratio under isothermal conditions with corresponding entropy change. Namely,

$$I/I_{\Delta S} = /[(S_1 - S_2)/R]$$

where $I_{\Delta S}$ is the reference mass flux through unit gas thickness for an arbitrarily chosen value of entropy change ΔS. Application of this equation to evaluation of diffusion coefficients for vapors in gases results in an agreement with available experimental data within 1 per cent at an average.

By analogy a similar relation for the thermal diffusion is derived. Using experimental results of over one hundred mixtures of great variety of gases it is proved that for all binary gas mixtures the linear relation

$$\Delta\lambda/\Delta\lambda_{\Delta S} = 1.986\ [(S_1 - S_2)/R]$$

holds over wide range of temperatures and concentration.

S. Smoleniec, South Africa

5564. Weitzsch, F., A new method for the treatment of gas dynamics problems for cases of large deviation from the thermodynamical equilibrium (in German), *Ann. Physik* **7,** 7/8, 403-417, Mar. 1961.

Starting with concept of arbitrarily small group of gas particles having Maxwell-Boltzmann equilibrium distribution expressed in terms of local mean velocity v and mean temperature T, approximate solution of Boltzmann equation is obtained. Summation is made over an infinitely large number of such groups with different values of v and T with the help of a space-and-time variable equilibrium function. In this process v and T lose their physical significance and become merely integration variables, expressions for the mean values of which are obtained. Procedure does not lead to direct integration of Boltzmann equation, but to some useful results, such as a differential equation for the special case of one-dimensional plane flow with no external force field. Results can be integrated for the shock wave based on the "Maxwell molecule" shock model. Arbitrarily strong shocks can also be treated without an excessive amount of labor. Method can be considered an extension of the Mott-Smith treatment, and should be of interest to physicists and engineers who deal with basic theoretical thermodynamics and the kinetic theory of gases. Only experience will demonstrate whether it has any special advantages for practical aerodynamicist dealing with shock-wave problems.

C. W. Smith, USA

5565. Tareeva, E. E., Free-energy computation for a gas of low density, *Soviet Phys.-Doklady* **5,** 3, 551-555, Nov./Dec. 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **132,** 3, 568-571, May 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

5566. Bundy, F. P., Effect of pressure on emf of thermocouples, *J. Appl. Phys.* **32,** 3, 483-488, Mar. 1961.

"Pressure" thermal emf's have been measured for constantan, Pt, Ni, alumel, Pt 10% Rh, Cu, chromel, and Ni 18% Mo for a ΔT of 100 °C over a pressure range 0 to 72 kbar. Corrections due to pressure for common thermocouples made of pairs of these metals have been deduced. A number of thermocouple pairs have been compared at temperatures up to 1200 °C and pressures up to 58 kbar. Below 200 to 300 ° the deviations between them agree quite well with the absolute data on single metals taken at ΔT of 100 °C. At higher temperatures the deviations diminish and generally reverse. It appears that the deviation δT of the readings of two thermocouples at a given pressure follow roughly the relationship $\delta T = A(P)\Delta T + B(P)\Delta T^2$, where ΔT is the temperature interval in the pressurized zone, $A(P)$ and $B(P)$ are functions of pressure (roughly linear), and $B(P)$ is generally opposite in sign to $A(P)$ and is large enough to dominate the $A(P)$ term at higher ΔT's.

From author's summary

Book—5567. Baehr, H. D., Mollier *i-x* diagrams for humid air in units of the international system of units [Mollier *i-x* Diagramme fur feuchte Luft in den Einheiten des Internationalen Einheitensystems] Berlin, Springer-Verlag, 1961, 23 pp. + 3 diagrams. DM 12. (Paperbound)

In order to facilitate the transition to the MKSA system of units in heat and refrigeration engineering, the author has undertaken the task of recalculating the properties of air-water vapor mixtures. In performing this task he took the opportunity to revise the values themselves, rather than to effect a mere conversion of units. The properties of air-water vapor mixtures are represented in the form of an enthalpy-moisture content diagram, first proposed by R. Mollier. This so-called i, x diagram is more popular in Germany and the Continent of Europe than in the English-speaking countries. A large-scale diagram is included in the pocket of the book, and an extensive table of properties permits the reconstruction of this simple diagram, if necessary. The Introduction contains a succinct description of the properties of the diagram. It appears that, at least in some countries, the advent of digital computers has not rendered the use of thermodynamic diagrams obsolete. The motivation for this diagram is the same as that for the one referred to in the following review.

J. Kestin, USA

Book—5568. Haussler, W., The Mollier *i-x* diagram for wet air and its technical application [Das Mollier *i-x* Diagramm fur fechte Luft and seine technischen Anwendungen] Dresden, Verlagsbuchhandlung Theodor Steinkopff, 1960, xii + 167 pp. + tables. DM 18. 30.

Compared with the diagram described in the preceding review, the present diagram is cast in the more conventional units: kilogram, kilopond, kilocalorie, meter, etc. The introductory part is considerably expanded and contains a discussion of the i, t (enthalpy-temperature), t, x (temperature-moisture content), as well as the i, x (enthalpy-moisture content) diagram, together with a brief description of instruments and line diagrams of installations used in air-conditioning and allied industries which serve as illustrations for the use of the Mollier diagram. The treatment is straightforward, except that a short section is devoted to the processes of compression and expansion in humid air. These are described by means of polytropic curves. The Mollier diagram appears in two forms, the conventional form for 1 atm and in a form in which variable pressure can be accounted for with reference to auxiliary nomograms. Auxiliary nomograms display enthalpies in kJ/kg.

J. Kestin, USA

5569. Mikhailov, V. V., An analytical representation of the thermodynamic function of dissociation of air (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **28,** 36-43, 1960.

A compact development of formulas for the effect on thermodynamic properties of air produced by dissociation into O, N, and NO. The analytical basis is the expression of free energy levels. Results are in well-known form. Data presented in graphical form indicate purported improvement over earlier SSSR data. No tabulations of basic constants for the calculations are given.

N. A. Hall, USA

5570. Nowak, E. S., Grosh, R. J., and Liley, P. E., A survey of *P-V-T* data for water in the critical region, *ASME Trans.* **83** C (*J. Heat Transfer*), 1, 1-13, Feb. 1961.

A comprehensive review is given of P-V-T data available for water at pressures from 2700 to 4000 psia, specific volumes from 0.025 to 0.125 cu ft per lb, and temperatures from about 680 to 800 deg F. Experimental and computed values of various investigations are given. A description of the various methods and formulas used to interpolate the original data is also given. The results indicate there is a lack of smoothed or computed values for the specific volumes of the superheated vapor at sufficiently close intervals in the critical region. This makes it difficult to interpolate accurately and derive such properties as density and coefficients of volume expansion and compressibility. Furthermore, there are significant differences between the data for superheated steam given in the various tables which can be attributed to erroneous methods of interpolating the original experimental data.

From authors' summary

5571. Joshi, K. M., and Saxena, S. C., Viscosity of polar gases (in English), *Physica* **27,** 3, 329-336, Mar. 1961.

Viscosity data for several polar gases have been interpreted in terms of a modified Stockmayer potential. Potential parameters have been evaluated by a graphical method. Computed values of viscosity have been compared with the experimental data as function of temperature. This procedure has thrown some light on the nature of intermolecular forces and has lead to the conclusion that the modified potential can be relied upon only for moderately polar gases. For highly polar gases, this potential may at best serve the purpose of an empirical correlating function for the experimental data.

From authors' summary

5572. Hill, R. W., and Lounasmaa, O. V., The thermodynamic properties of fluid helium, *Phil. Trans. Roy. Soc. Lond.* (A) **252,** 1013, 357–395, Mar. 1960.

5573. Dolgopolov, D. G., The dissipation function and symmetry of the kinetic coefficients of helium II (in Russian) (Uch. Zap. Khar'kovsk. In-ta, Vol. 98, 1958), *Trudi Fiz. Otd. Fiz.-Matem. Fak.* **7,** 45–48, *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13794.

The equation of continuity for entropy is derived from the kinetic equation. Based on this derivation, dissipation terms are obtained in the equation of continuity for the entropy. Terms of the second approximation for the equations of the hydrodynamics of helium II are found; that is, terms proportional to the square of the length of the free run of the elementary excitation.

Yu. A. Bychkov
Courtesy Referativnyi Zhurnal, USSR

5574. Kudryavtsev, B. B., Some of the thermodynamical and mechanical properties of a liquid (in Russian), Primenenie Ul'traakust. k Issled. Veshchestva. no. 6. Moscow, 1958, 53–67; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13163.

A semi-empirical relation is advanced for the relation of the velocity of the propagation of sound in a liquid to the potential energy of the interaction of the molecules, the temperature and some of the physical parameters of the liquid. For the purpose of calculating the potential energy of the molecular interaction of the liquid a semi-empirical relation of this energy to the volume is employed. Theoretical data are compared with the experimental data obtained when using various solvents (acetone, benzol, etc.). Satisfactory agreement was obtained for the velocity of propagation of sound in benzene and carbon tetrachloride in the form of experimental curves and the theoretical at various pressures on the medium (up to 1000 atm). A. I. Golubev
Courtesy Referativnyi Zhurnal, USSR

Book—5575. Goldsmith, A., Waterman, T. E., and Hirschhorn, H. J., Handbook of thermophysical properties of solid materials: Vol. 1, Elements, New York, Pergamon Press, 1961, vi + 758 pp. $90 the 5-volume set.

5576. Martinovsky, V. S., and Voytko, A. M., The efficiency of the Ranque vortex tube at low pressure (in Russian), *Teploenergetika* no. 2, 80–85, Feb. 1961.

5577. Castro, P. S., and Happ, W. W., Performance of a thermoelectric converter under constant heat flux operation, *J. Appl. Phys.* **31,** 8, 1314–1317, Aug. 1960.

Authors derive expressions for optimum internal and load circuit electrical resistances of a thermoelectric converter with constant heat input to the hot junction. Comparison with constant temperature mode of operation shows appreciable differences in the optimum conditions. Graphs of optimum load-to-internal resistance ratios are provided both for a fixed internal resistance and a fixed load resistance. Calculations are performed for a single thermocouple but immediate extension to multiple couples, electrically in series and thermally in parallel, is indicated.

J. R. Moszynski, USA

5578. Kebbon, E. R., Bimetal thermometers, *Instrum. Control Systems* **34,** 5, 841–845, May 1961.

5579. Nelson, R. C., Temperature measurement by filled system, *Instrum. Control Systems* **34,** 5, 849–853, May 1961.

5580. Mack, D. R., Linearizing the output of resistance temperature gages, *Experimental Mech.* **1,** 4, 122–127, Apr. 1961.

Heat and Mass Transfer

(See also Revs. 5179, 5243, 5419, 5475, 5483, 5487, 5489, 5490, 5491, 5495, 5562, 5563, 5644, 5645, 5651, 5678, 5721, 5773, 5774, 5803)

5581. Bukharin, V. I., and Danilovskaya, V. I., Approximate solution of nonsteady problems in heat conduction (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **30,** 112–118, 1960.

Paper considers the problem of an infinite hollow cylinder of radii a and b which is at constant temperature T_0 at time $t = 0$ and which exchanges heat with systems of temperature $T_1(t)$ and $T_2(t)$ at $r = a$ and $r = b$, respectively, with the proviso that the coefficients of heat transfer b_1 and b_2 are also time-dependent. An approximate solution in the form of the quadratic polynomial $T = b_1(t) + b_2(t)r + b_3(t)r^2$ is obtained. The functions b_1, b_2, b_3, are given in the form of rather complicated integrals, and the approximation consists in the fact that at $t = 0$ only the average temperature of the cylinder is equal to T_0.

The same method is then applied to a composite slab consisting of two layers of different materials. J. Kestin, USA

5582. Khaskind, M. D., Thermal waves in the ground beneath insulated coolers, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **24,** 2, 377–389, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

General problem considered is heat transfer between the ground and a cooler of finite width but infinite length resting on an insulated base. Uniqueness of the solution of the boundary problem is demonstrated and the solution obtained for the nonsteady components of temperature as an infinite series of Mathieu functions, coefficients being left to be determined in terms of infinite determinants. Approximate solutions for short period components are given, and edge effects discussed. Final section considers damping effects of insulation for very wide cooler.

Reviewer finds paper interesting as an example of ingenious solution of an unusual boundary problem, without using transform methods. R. P. Pearce, Scotland

5583. Reich, A. D., and Madigan, J. R., Transient response of a thermocouple circuit under steady currents, *J. Appl. Phys.* **32,** 2, 294–301, Feb. 1961.

A solution for transient response of a thermocouple circuit functioning as a Peltier cooler at constant current is presented. The solution applies to cases involving constant properties, such as resistivity, thermal conductivity, specific heats, and density of material, as well as constant Peltier voltage and Joule heat. The resulting time-dependent temperature consists of the sum of two parts: one due to diffusion of Joule heat and the other due to diffusion of Peltier heat. As pointed out by the authors, the interesting situation is that with time-dependent current density. A method of measurement of thermal conductivity was suggested from the basic relations. It would be interesting to extend this study to include heat transfer due to potential gradient (which also has an effect on the measurement of thermal conductivity) and the effect of temperature gradient on current flow as outlined for instance, in Sec. 10.3, 10.4 of D. ter Haar, "Statistical Mechanics," Rinehart and Co., Inc., New York. S. L. Soo, USA

5584. Rogers, G. F. C., Heat transfer at the interface of dissimilar metals, *Inter. J. Heat Mass Transfer* **2,** 1/2, 150–154, Mar. 1961.

One investigation into the resistance to heat flow at the interface of metals in contact revealed that when the metals were dissimilar the resistance depended upon the direction of heat flow. This note presents further results which confirm the existence of the phenomenon and which indicate that the effect could be associated with the mechanism of conduction at the points of metallic contact. From author's summary

5585. Perelman, T. L., The temperature field in a finite cylinder with inner sources (in Russian), *Inzhener. Fiz. Zh.* **3**, 5, 138–144, May 1960.

Heat-conduction problem in a cylinder $0 \leq r \leq R$, $0 \leq z \leq 1l$ with inner heat-sources $Q(r, z, \tau)$ and constant initial temperature t_0 is considered. Convection heat exchange (according to Newton's law) on the surface is investigated. Conditions

$$\left.\frac{\partial t}{\partial x}\right|_{x=0} = 0, \qquad t|_{x=0} = t_a = \text{const} \qquad [1]$$

on the base and on the top of the cylinder are prescribed.

After expressing the problem in dimensionless quantities, author uses Hankel and Fourier transforms and presents explicit solution of the problem (in form of infinite series). Particularly, he investigates a special type of heat-sources function.

The second part of the article concerns various limit conditions for $x = 0$ and $x = l$:

$$\left.\frac{\partial t}{\partial x}\right|_{x=0} = \left.\frac{\partial t}{\partial z}\right|_{x=l} = 0, \qquad [2]$$

$$t|_{x=0} = t|_{x=l} = t_a, \qquad [3]$$

$$\left.\frac{\partial t}{\partial z}\right|_{x=0} = 0, \quad \left.\frac{\partial t}{\partial z}\right|_{x=l} + b(t - t_a)|_{x=l} = 0. \qquad [4]$$

K. Rektorys, Czechoslovakia

5586. Bailey, H. R., Conduction-convection from a cylindrical source with increasing radius, *Quart. Appl. Math.* **18**, 4, 325–333, Jan. 1961.

The physical problem considered is as follows: Air is injected along a line in an infinite porous solid and burns on an expanding cylindrical surface with radius $r_f(t)$. Heat transfer takes place both by conduction in the solid and by convection from the solid to the air. The defining field equations then take the form

$$\partial^2 T_s/\partial r^2 + r^{-1}\partial T_s/\partial r - a^2 \partial T_s/\partial t + k^{-1}\Phi(r, t) = k^{-1} b(T_s - T) = r^{-1} P(t)\partial T/\partial r$$

where T_s is the temperature of the solid, T is the temperature of the gas, k is the conductivity of the solid, a^2 is the reciprocal diffusivity, b is the convection coefficient, $\Phi(r, t)$ is a heat source function describing the heat released by combustion and $P(t)$ describes the air injection program. Two cases of particular interest in underground combustion are treated: (*a*) constant velocity source, $r_f = vt$, $P(t) = k_1 v^2 t$, $\Phi(r, t) = qv\delta(r - r_f)$ and (b) constant injection rate, $r_f^2 = 2Vt$, $P(t) = 2n$, $\Phi(r, t) = qVr_f^{-1}\,\delta(r - r_f)$. The quasi-stationary state solution approached for sufficient large values of time to problem (a) is obtained. For problem (b), with infinite convection coefficient b, it is found that $T(r, t) = T(y)$ with $y = r/r_f$. The problem thus reduces to one involving an ordinary differential equation which is solved in terms of the incomplete gamma function. J. H. Weiner, USA

5587. Smirnov, V. A., Verevochkin, G. E., and Brdlick, P. M., Heat transfer between a jet and a plate held normal to flow, *Inter. J. Heat Mass Transfer* **2**, 1/2, 1–7, Mar. 1961.

The heat transfer between a submerged jet of liquid and a plate held normal to the flow is studied experimentally. Three heat-transfer regions varying in relative length of jet b/d are established. The rated formulas satisfactorily agreeing with the experimental data of other investigators are recommended.

For the ranges $b/d \leq 0.5$, $0.5 < b/d > 10.0$ rated formulas are given. The rated formulas obtained are valid for a wide range of variable main parameters, defining heat-transfer processes of the jet streamline of plates normal to the flow. For the ranges $0.5 < b/d < 10.0$ and $b/d > 10.0$ particular rated formulas which include the angle of attack are recommended. The correlation factor for the angle of attack $\varepsilon\psi$ is found from one of the figures.

The influence of the walls which limit the flow of jet heat transfer is investigated. From authors' summary

5588. Zhukauskas, A. A., Shlanchyauskas, A. A., and Yaronis, E. P., An investigation of the effect of ultrasonic waves on heat transfer in liquids (in Russian), *Inzhener.-Fiz. Zh.* **4**, 1, 58–62, Jan. 1961.

Experiments are made in which heat is transferred from a solid to water or transformer-oil without and with irradiation by ultrasonic waves. With a frequency of 697 kilocycles per second a marked increase in the heat-transfer coefficient is found. Quantitative results are shown in graphs. Further experiments were made at a frequency of 610 and 27 kilocycles per second.

R. Eisenschitz, England

5589. Kudryavtsev, E. V., and Shumakov, N. V., Effect of dimension and material of solid bodies on the process of transient heat exchange (in Russian), *Inzhener.-Fiz. Zh.* **4**, 1, 63–70, Jan. 1961.

Measurements are made with metal cylinders of silver, copper, zinc, cobalt and aluminum immersed in water. The rate of heating and of cooling is studied under conditions of free and of forced convection. Results are shown in graphs in which the heat flow is plotted against time. Hence heat-transfer coefficients are calculated. It is found that they vary with time and that they depend upon the mean difference of temperature between solid and liquid. Discussing the result the authors call for a new approach to the problem of transient heat transfer.

Reviewer feels that the authors' results are by no means unexpected. The concept of a "heat-transfer coefficient" is very crude. There is hardly any reason to believe that it should apply in its simple form to conditions remote from stationary heat transfer. R. Eisenschitz, England

5590. Perelman, T. L., The distribution of temperatures in a cylinder with internal heat generation and cooling by a turbulent flow (in Russian), *Inzhener.-Fiz. Zh.* **3**, 11, 72–76, Nov. 1960.

The problem of heat transfer by convection between a finite cylinder $0 \leq r \leq R$, $0 \leq z \leq l$ with arbitrary inner heat sources and its cooling by a turbulent liquid flow is considered. Under some rather simplifying assumptions, differential equations of the problem with corresponding boundary conditions are written.

Using the Laplace transform, the problem is reduced to solving two linear integral equations. This latter problem is further reduced to the solving of one Fredholm's integral equation only, the solution of which (with help of the Fredholm resolvent) is presented.

Particularities and discussion of the solution will be published later. K. Rektorys, Czechoslovakia

5591. le Fur, B., Heat convection in a laminar region with a pressure gradient and an arbitrary wall temperature distribution in a fluid of constant thermal properties (in French), *Inter. J. Heat Mass Transfer* **1**, 1, 68–80, June 1960.

Author uses a successive approximation method to solve laminar boundary-layer equations for flow past a wall with a pressure gradient superposed. Frictional heating is included, and results are applicable to flow at low, as well as at high, Prandtl numbers. Convection coefficients calculated to a first approximation for flow past a wedge agree with exact values given by Brun to 15%, rather better than those previously given by Lighthill. Friction coefficients agree to 6% with those calculated by Hartree.

R. P. Pearce, Scotland

5592. Voskresenskii, K. D., and Turilina, E. S., Effect of internal sources of heat in a streaming fluid upon the heat transfer from a tube (in Russian), Konvektivnyi i Luchistyi Teploobmen, Moscow, Izdatel'stvo Akad. Nauk SSSR, 1960, 7–15.

Fluid is assumed to be in movement in a tube. Heat is exchanged through the surface of the tube both because of a possible difference of external and internal temperature and of heat production (chemical or otherwise) within the fluid. An expression for Nusselt's number is obtained in which the effect of the production of heat is explicitly exhibited. Whether or not heat transfer is influenced by the production of heat depends on the velocity of flow. In particular, if this velocity is high the production of heat tends to diminish the heat-transfer coefficient.

R. Eisenschitz, England

5593. Ambrazevichyus, A., and Zhukauskas, A., The influence of the direction of the thermal flow on the heat emission of a plate in a flow of liquid (in Russian), *Trudi Akad. Nauk LitSSR* **B4(16),** 163–169, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13694.

The influence is investigated theoretically of the direction of the thermal flow on the heat emission for the simplest case: the flow-about of a plate with a laminar flow in the boundary layer. A comparison is given of the parameter taking into account the direction of the thermal flow, obtained experimentally with the corresponding parameter obtained on the basis of Kharoi's theoretical calculation [*Trans. Japan. Soc. Mech. Engrs.* **20,** 92, 257–261, 1954]. The convergence of the data is good; a criterial relation is obtained for the local coefficient of the heat emission of the plate and for the mean with a laminar boundary layer which agrees well with the experimentally obtained relations.

From authors' summary

Courtesy Referativnyi Zhurnal, USSR

5594. Ambrazevichyus, A., and Zhukanskas, A., Heat emission of a plate in a flow of liquid (in Russian), *Trudi Akad. Nauk LitSSR* **B4(16),** 171–176, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13695.

A description is given of the experimental investigation of heat emission from a plate in a flow of air and water when the liquid is being heated and cooled at Reynolds numbers of 10^5 to 10^7 and in a range of temperatures from 18 to 90°. The experiments were carried out on a copper plate 250 × 50 × 10 mm, situated in a hydraulic contour. The temperature of the wall was measured by means of 23 thermo couples (copper-constantan, diameter 0.15mm). The mean temperature was determined by the method of graphical integration. The change in the temperature of the water flowing over the plate was measured by means of a difthermocouple. All the physical parameters of the liquid are referred to the mean temperature of the flow which was measured by a precise laboratory thermometer and the control thermocouple. It was established that the relation of the heat emission to the direction of the thermal flow is well estimated by the authors [See preceding review] by the previously proposed parameter Pr_f/Pr_w to a degree of 0.25. The degree of Prandtl's criterion was 0.43. A formula is obtained for the calculation of the plate in the flow of liquid which confirms the relation put forward by M. A. Mikheev. The formula is more simple for a flow of air; good agreement is attained with the data of previous studies. From authors' summary

Courtesy Referativnyi Zhurnal, USSR

5595. Maslovskii, M. F., Solution of a differential equation for heat exchange with a laminar regime for the motion of the liquid in the tube (in Russian), *Trudi Mosk. In-ta Khim. Masbinostr.* **15,** 3–23, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13710.

An equation is solved which describes the steady heat emission in the axial flow of a liquid in the presence of a "Poiseuille" distribution of the velocity. In contrast to cases previously investigated the author retains the second derivative in the direction of the axis of the tube. It is assumed that this will enable the author to ascertain the temperature at all points right up to the inlet portion although the accepted "Poiseuille" distribution of velocity renders the equation unsuitable in this region. The equation is put through the Laplace conversion. The ordinary differential equation obtained has a solution in special functions.

V. I. Merkulov

Courtesy Referativnyi Zhurnal, USSR

5596. Gutarev, V. V., Heat exchange in the initial portion of a straight tube with different inlet forms (in Russian), *Trudi Mosk. In-ta Khim. Masbinostr.* **15,** 25–40, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13711.

The character of heat emission in the first portion of a round tube in relation to the inlet conditions is experimentally investigated. The tube is made of copper, with a length of 1806 mm and a diameter of 20/30 mm. The investigations were carried out with water; Reynolds numbers varied within the limits of 10,000–60,000. For the purpose of altering the inlet conditions 5 removable caps were prepared, classified as regards construction as: a smooth inlet (initial diameter 50 mm), a smooth bend (90°; $R = 3d$), and others. Temperatures were recorded of the liquid, the tube's surface and the emitted heat. The local coefficient of heat emission was found. Graphs and empirical formulas are provided, which give the relation of the local Nusselt number to the Reynolds and Prandtl numbers and the relation x/d (x being the distance from the inlet and d the diameter of the tube). It is shown that the local coefficient of heat emission diminishes, generally, in proportion to the increase of the distance from the inlet: in cases of smooth inlet and bending monotonously in the case of a sharply ending inlet, a nonmonotonous relation is noticed. It is indicated that alterations in the conditions at the inlet result in obtaining a different distribution of the Nusselt number N along the length of the tube. It is demonstrated that the influence of inlet conditions (for the range of types of capping investigated) is only in operation when $x < 15d$. With $x > 50d$ the limit of value for the coefficient of heat emission is reached which does not depend on x and on the form of the inlet. The data obtained are compared with the results recorded by other authors. G. Z. Gershuni

Courtesy Referativnyi Zhurnal, USSR

5597. Petukhov, B. S., and Tsvetkov, F. F., Calculation of laminar forced convection for a fluid flowing in a pipe at small Peclet numbers (in Russian), *Inzhener.-Fiz. Zh.* **4,** 3, 10–17, Mar. 1961.

Paper addresses itself to the elucidation of the very topical problem of the discrepancies between calculation and experiment relating to the transfer of heat by laminar convection to molten metals flowing through pipes at very low Péclet ($Pe = Re \times Pr$) numbers. The reasons for the discrepancies are sought in the effect of axial heat conduction which is usually disregarded, and which becomes small at $Pe \approx 10$ or more. The problem is solved by dividing the tube into n concentric annuli and by writing down the heat balance equations for them. The equation for the annulus nearest to the wall contains the heat flux, the equation for the central elementary tube contains one term fewer than the others. Thus the problem is reduced to the solution of n ordinary differential equations of second order. Each of these determines the axial temperature variation for the particular annulus, and the constants of integration are determined from the known conditions at inlet and exit for the whole pipe. Explicit formulas are given for four steps in the radial temperature distribution.

An analysis of the results in terms of the effect of the Péclet number shows that at $Pe \approx 10$ the thermal inlet length differs little from that which is obtained when axial conduction is neglected. The longitudinal variation of the Nusselt number depends strongly

on Pe, and markedly differs from $Pe \rightarrow \infty$ up to $X = x/Pe \cdot d \simeq 4$ for $Pe = 1$, or progressively less for increasing values of Pe.

An experimental verification involving mercury shows good agreement for the over-all Nusselt number Nu_∞, the scatter of experimental points being confined to a band of +9% and −5% with respect to the calculated value. This verification is not quite conclusive since only Re was varied in the product $Re \times Pr$ to effect a variation in Pe. J. Kestin, USA

5598. Usmanov, A. G., Generalization of experimental data for viscosity and thermal conductivity of liquid metals (in Russian), Konvektivnyi i Luchistyi Teploobmen, Moscow, Izdatel'stvo Akad. Nauk SSSR, 1960, 97–106.

Equation for relative rate of molecular transport in terms of entropy change in rarefied gases is applied without reservation to liquid metals. Thus, mass- and heat-transfer relations in liquid metals are given as follows:

$$(\eta \Delta t)/(\eta_{\Delta s} \Delta t_{\Delta s}) = f_1[(S_1 - S_2)/R]$$

$$q/q_{\Delta s} = f_2[(S_1 - S_2)/R]$$

where subscript Δs denotes reference values corresponding to an arbitrarily chosen entropy change Δs. Since heat flux across layer of unit thickness $q = \lambda \Delta t$, therefore both dynamic viscosity η and thermal conductivity λ may be evaluated for temperatures beyond limits of existing data.

Curves representing above relations are plotted from experimental data for Na, K, Sn, Pb, Bi and Hg. For Na and K an excellent correlation is shown. For Sn, Pb, Bi and Hg average deviation of experimental points from the curves is about 4 per cent. In spite of that, reviewer is dubious regarding theoretical validity of this generalization. S. Smoleniec, South Africa

5599. Smirnov, A. G., An experimental investigation of the free thermal convection of mercury in a closed tube in a magnetic field (in Russian), *Ucb. Zap. Permsk. In-ta* **15**, 4, 5–58, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13097.

A detailed exposition is given of the procedure and of the results of the study of the fixed thermal convection of mercury filling long glass tubes which were being heated; the inner diameters of the tubes were 5.6 to 13.4 mm, they were either vertical or inclined 30° to the vertical; there was either no magnetic field or an external magnetic field up to 2000 Hertz, perpendicular to the axes of the tubes. Based on the readings of a network of thermocouples fixed on the external surfaces of the tubes a deduction is advanced regarding the existence simultaneously of three portions with different mechanisms for the heat transfer provided a certain standard of heating is carried out: a turbulent portion—close to the heating element; a laminar portion with a length 3 to 10 times the diameter of the tubes—in the central part of the tube; and a portion near the cooling unit in which the heat transfer operates fundamentally by means of the mechanism of molecular heat conductivity. The distribution of the temperature in the first and third portions is exponential, and in the second, linear. The magnetic field is laid on the whole length of the laminar portion by two means: perpendicularly to the plane of the interface of the ascending and descending flows and parallel to that plane. In small magnetic fields (up to 110 Hertz and 300 Hertz for the first and second means, respectively) the mean gradient of the temperatures along the part of the tube situated in the field increases linearly with increase of the square of the magnetic induction, which agrees with the results of the theoretical investigations given in the paper. In strong fields the mean gradient of temperature does not depend on the field. In a less detailed fashion this study is already available in the literature [A. G. Smirnov, *Dokladf Akad. Nauk SSSR* **115**, 2, 284–286, 1957; *Zh. Tekhn. Fiz.* **27**, 10, 2373–2380, 1957; *Zh. Tekhn. Fiz.* **28**, 7, 1549–1555, 1958].

G. F. Shaidurov

Courtesy Referativnyi Zhurnal, USSR

5600. Zierep, J., Thermo-convective cellular flow in the case of nonuniform heating of the basic surface (in German), *ZAMM* **41**, 3, 114–125, Mar. 1961.

The equations of fluid flow for laminar flow, heat transport, continuity, and state are solved approximately for a two-dimensional system in which the lower surface has stepwise temperature variation in space. The upper surface is maintained at a constant temperature. By assuming a linear variation of temperature between the two surfaces the author derives solutions of the flow equations. Two types of solutions are shown to be possible, one periodic and the other exponential. Over one step of the stepwise temperature variation of the base one solution can be periodic and corresponds to the cellular flow, whereas over the other step exponential solution applies and joins the first solution in a continuous manner.

Reviewer feels the paper to be quite worthwhile and recommends it for study to any who are interested in this particular problem.

W. A. Wolfe, Canada

5601. Gershuny, G. Z., and Zhukhovitsky, E. M., Transmission of heat across a vertical slit of rectangular section by intense convection (in Russian), *Inzbener.-Fiz. Zb.* **3**, 12, 63–67, Dec. 1960.

Fluid is embedded in a cavity within a solid mass. Two vertical parallel and opposite walls have different temperatures which are assumed to be independent of time and uniform over the surface of the wall. The resulting convective movement of the fluid is investigated. It is assumed that boundary-layer theory can be applied to a thin layer of the liquid near the walls whereas in the interior of the cavity the effects of viscosity can be ignored. On these assumptions a solution of the equations of motion is obtained. It is found that the smooth flow of heat from the hot to the cold wall is strongly interfered with by convective effects so that at the bottom heat flows into the liquid from both sides and at the top heat flows out to both sides. Simultaneously an intense flow of heat is maintained in upward direction. Author's results are compared with alternative deductions. It is found that agreement is not complete. There are no comparisons with measurements.

R. Eisenschitz, England

5602. Martini, W. R., and Churchill, S. W., Natural convection inside a horizontal cylinder, *AIChE J.* **6**, 2, 251–257, June 1960.

Paper describes the rare case of measurements of velocity and temperature fields within two vertical halves of the wall of a 4.3-in. I. D., 3-ft long horizontal cylinder maintained at different uniform temperatures (difference ranging from 3.5° to 367°F). Temperature traverses and velocity measurements enabled determining rate of circulation of air inside cylinder and local rate of heat transfer between wall and air.

Air was found to be mainly stagnant in central region, while it circulated around wall of cylinder with a velocity increasing with increasing wall temperature difference.

Local heat-transfer coefficient varied considerably with angle but increased only slightly with wall temperature difference, while over-all Nu—based on wall temperature difference—was approximately constant at 7.

Trials, using magnetic drum computers, are also described, showing possibilities and limitations of numerically solving involved partial differential equations for conservation of mass, energy and momentum for this system.

M. A. Saleh, Egypt

5603. Detra, R. W., and Hidalgo, H., Generalized heat transfer formulas and graphs for nose cone re-entry into the atmosphere, *ARS J*, **31**, 3, 318–321, Mar. 1961.

Utilizing the research results of previously reported investigations of the laminar, turbulent and radiative heat transfer in dis-

sociated air, some generalized formulas for calculating heat transfer are given. Graphs for determining the laminar heat transfer, momentum thickness Reynolds number, and turbulent heat-transfer distributions around an axisymmetric body are also given. These heat-transfer correlations are valid for velocities between 6000 and 26,000 fps and for altitudes up to 250,000 ft. This range of velocities and altitudes covers the important re-entry regime of practical re-entry trajectories having interest today. In the last section of this report these generalized results are specialized for ICBM nose cone re-entry applications. These formulas and graphs may be found useful for making rapid engineering estimates and preliminary design evaluations of the heating problems associated with re-entry into Earth's atmosphere.

From authors' summary

5604. Short, W. W., Heat transfer and sublimation at a stagnation point in potential flow, *ASME Trans.* **82**E (*J. Appl. Mech.*), 4, 613–616, Dec. 1960.

A simplified analysis is presented of heat and mass transfer at a stagnation point of an ablating sphere. The fluid is assumed to be inviscid and incompressible; diffusivities for heat and mass transfer are assumed to be constant and equal. The predicted rates of heat transfer in air in the absence of mass transfer are about 40% greater than those computed from a boundary-layer theory [*J. Aero. Sci.* **19**, 570–571, 1952]. Experimental values shown are mostly intermediate between the two theories.

The reduction in heat transfer due to mass transfer is calculated for values of Re · Pr ranging from 2 to infinity. The reduction is insensitive for variations of this paramater in the range 1000 to infinity. D. A. De Vries, Netherlands

5605. Wood, R. M., and Tagliani, R. J., Heat protection by ablation, *Aero/Space Engng.* **19**, 7, 32–38, 45, July 1960.

A metal load-carrying structure covered with a protective coating is discussed and analyzed as a method of dissipating transient heating of hypersonic vehicles. A thermodynamic analysis utilizing various properties of coating materials is made to describe the effectiveness of different materials. A graphical presentation summarizes relative coating weights required of different coating materials for various environmental situations. One critical assumption made in the analysis is the replacement of the actual heat input curve by a square wave input. The materials considered include teflon, low density teflon, polyethylene, phenolic nylon, phenolic fiberglass and quartz. R. J. Mindak, USA

5606. Hoshizaki, H., Mass transfer and shock-generated vorticity, *ARS J.* **30**, 7, 628–634, July 1960.

The effects of shock-generated vorticity and mass transfer on stagnation point heat-transfer rates are investigated. Numerical solutions obtained for the complete incompressible Navier-Stokes equations, considered in the flow region between the bow shock and the surface of spheres and cylinders for boundary conditions applied immediately behind the shock, show that the reduction in heat-transfer rate attributed to mass injection is substantially less than predicted by boundary-layer theory at $N_{Re} < 10^3$ for spheres and $< 10^4$ for cylinders. It would be beneficial to have some experimental data to check author's solutions, because of the importance of the problem. R. J. Mindak, USA

5607. Pomerantsev, A. A., Heat transfer of rarefied gas flowing round a wall: Part 1 (in Russian), *Inzbener.-Fiz. Zb.* **3**, 5, 3–11, May 1960.

Article deals with the problem of heat exchange between a wall and a slip flow of a rarefied gas. Using well-known concepts and theorems of the classical kinetic theory of gases, the author develops analytical relationships for heat exchange and transfer for dense and rarefied flows over a wall, and offers both general and numerical solutions of the equations of flows of this kind. The numerical tables, diagrams and clearly presented boundary conditions make the article pleasantly readable and the final results may be readily checked. It is obvious both from the bibliography and from the article that author is unaware of papers on the subject published in the West.

G. A. Tokaty and D. J. Huggett, England

5608. Kivel, B., Radiation from hot air and its effect on stagnation-point heating, *J. Aerospace Sci.* **28**, 2, 96–102, Feb. 1961.

The heating of the stagnation region of a blunt body by radiation from the hot air in the shock layer is investigated for flight speeds up to 50,000 ft/sec by using experimental shock-tube data, supplemented by theoretical estimates. Nonequilibrium effects which modify the radiation predictions at high altitudes ($\geq$ 30 miles) are pointed out. The radiation is compared with the aerodynamic heating and is found to be important at high velocities ($\geq$ 30,000 ft/sec) and low altitudes ($\geq$ 25 miles). For this flight regime the dominant radiation results from the capture of electrons by nitrogen ions.

From author's summary by D. B. Spalding, England

5609. Granet, I., and McIlroy, W., Optimum radiant straight fin with exponential sides, *ARS J.* **31**, 1, 80–82, Jan. 1961.

The design of a fin radiating into space is briefly considered and it is shown that analytical methods are available for many shapes of fin over and above that with exponential sides specifically discussed by authors.

Paper appears to be very condensed and this, together with some ambiguity in the presentation, makes it difficult to follow, or to judge how much novel material is contained in addition to that in the recent work to which reference is made. A clearer exposition of the optimum designs arrived at would also have been welcome.

G. G. Thurlow, England

5610. Krishnan, K. S., and Sundaram, R., The distribution of temperature along electrically heated tubes and coils: Part 1, Theoretical, *Proc. Roy. Soc. Lond.* (*A*) **257**, 1290, 302–315, Sept. 1960.

Axial temperature distribution in a thin tube electrically heated in vacuum is considered. An approximate solution is obtained for the radiant heat transfer within the core of the tube, assuming grey radiation and that the principal contribution to the radiation received at any axial position comes from regions at most several diameters away. This permits expansion of the temperature in a Taylor series, retaining a few terms only. The effect of reflections is computed assuming purely specular reflections. Analogies between the radiational conductivity of the core and that of a rarefied hot gas and the thermal conductivity of a dielectric at low temperatures are pointed out. A general solution for the temperature distribution in the tube is obtained and an extension to closely wound coils is indicated. J. R. Moszynski, USA

5611. Filimonov, S. S., Khrustalev, B. A., and Adrianov, V. N., Measurement of combined convective and radiant heat transfer by the method of two radiometers (in Russian), Konvektivnyi i Luchistyi Teploobmen, Moscow, Izadatel'stvo Akad. Nauk SSSR, 1960, 133–144.

Separate measurement of convective and radiant heat-transfer components by two-radiometer method was originally proposed by V. S. Kocho, "Stal," no. 3 1950. Here this method is analyzed and validity of assumptions involved verified experimentally. Radiometers used are of calorimetric type capable of measuring total heat transferred to receiver which is cooled by circulating water. In principle method is based on measuring total heat-transfer rates q_1 and q_2 to the receivers of emissivities A_1 and A_2 respectively. These values are then used for calculation of the in-

cident radiation density E, and convective component q_c from the relations

$$E = (q_1 - q_2)/(A_1 - A_2)$$

$$q_c = (A_2 q_1 - A_1 q_2)/(A_2 - A_1)$$

derived on assumptions E and q_c are the same in both radiometers. Using three radiometers sighted into a combustion chamber, and computing q_c values from three pairs of measurements these assumptions are reasonably justified. It is concluded, therefore, that two-radiometer method results are sufficiently accurate for practical purposes. S. Smoleniec, South Africa

5612. Adrianov, V. N., Radiometric instrument for measurement of radiant flux (in Russian), Konvektivnyi i Luchistyi Teploobmen, Moscow, Izdatelśtvo Akad. Nauk SSSR, 1960, 145–149.

Construction of a high precision total-radiation pyrometer is given, and methods of prevention of possible errors discussed. The body is thermostatically controlled, and dry air at constant temperature is continuously fed into the chamber consisting of an elliptical mirror. Author claims high accuracy in measurements of radiant energy under industrial and laboratory conditions. Only one quantity is to be measured, i.e. either a thermopile emf, or thermistor resistance. Application to automatic control of furnaces is not excluded. S. Smoleniec, South Africa

5613. Beerman, H. P., High temperature black body radiation source, *Bull. Amer. Ceram. Soc.* **40,** 5, 308–309, May 1961.

An isothermal (black body) radiation source is described which operates up to 1650 °C as standard source of thermal radiation for the calibration of pyrometers and infrared detection and measurement systems. Through the use of a conical cavity an effective total emissivity of better than 0.99 is achieved. With slight indicated changes the range of the instrument could be extended to approximately 1850 °C. From author's summary

5614. Chin, J. H., and Churchill, S. W., Incorporation of error function absorption coefficient in transport equation, *Quart. Appl. Math.* **18,** 1, 93–96 (Notes), April 1960.

Authors describe how the error function absorption coefficient can be incorporated in a solution of the radiative transport equation. This technique permits an averaging process which is helpful in considering radiative transfer through absorbing media.
E. Sunderland, USA

5615. Bennett, J. A. R., Collier, J. G., Pratt, H. R. C., and Thornton, J. D., Heat transfer to two-phase gas-liquid systems: Part 1, Steam-water mixtures in the liquid-dispersed region in an annulus, *Trans. Inst. Chem. Engrs.* **39,** 2, 113–126, Apr. 1961.

Preliminary heat-transfer rates and pressure drop data have been determined for two-phase steam-water mixtures in the liquid-dispersed region at substantially atmospheric pressure in an electrically heated test section. The latter consisted of a vertical precision bore borosilicate glass tube in which was located an electrically-heated coaxial stainless steel tube. Two sizes of test section were employed having 0.375 and 0.623 in. O.D. steel tubes inside 0.552 and 0.866 in. I.D. respectively glass tubes.

Point values of the two-phase heat transfer coefficient were determined for a range of mass flowrates and steam qualities using heat fluxes up to 158,550 Btu/h ft^2. Three distinct heat transfer regions have been distinguished depending on the steam dryness. Below 15% dryness, there is evidence to suggest that the mechanism of heat transfer is probably governed by considering nucleate boiling while at higher steam qualities (up to approximately 55–65%) a forced convective mechanism is suggested. Beyond 65% dryness, the heat-transfer rate decreases and in the limit approaches the value set by the dry-steam coefficient.

In the absence of a fundamental knowledge of the hydrodynamics of the system, attempts have been made to correlate the data in the forced convective region by a modified form of the Guerrieri and Talty equation. From authors' summary

5616. Pariset, E., and Hausser, R., Frazil ice and flow temperature under ice covers, *Engng. J. Montreal* **44,** 1, 46–49, Jan. 1961.

The frazil (free floating) ice particles in a river are interpreted as sediment particles with negative settling velocity. They have the tendency of attaching themselves to the ice cover at the water surface when they reach the surface. Their tendency to impede the operation of turbines depends on the supercooling of the ice particles. Their number in the flow under an ice cover is predicted from an equation of thermal equilibrium for the flow.
H. A. Einstein, USA

5617. Rao, R. D., Desai, H. S., and Gogate, D. V., A note on heat transfer and film boiling, *Indian J. Phys.* **34,** 10, 456–460, Oct. 1960.

Authors experimentally studied nucleate and stable film boiling in water, turpentine, napthalene and carbontetrachloride at atmospheric pressure from wires of several metals and sizes (1 to 2 mils diameter). They conclude that the material and wire dimensions do not affect peak heat flux, but the coolant did. Work was similar to others (specifically, Nukiyama, *Soc. Mech. Engrs. Japan* **37,** no. 206, p. 267, 1934). However, the conclusion that the material does not affect peak heat flux is not in agreement with Farber and Scorah [*ASME Trans.* **70,** pp. 369–389, May, 1948] and others. The effect of the material may be associated with surface roughness, wettability, or some other surface variables not controlled in the experiment. R. J. Fritz, USA

5618. Cess, R. D., Laminar-film condensation on a flat plate in the absence of a body force (in English), *ZAMP* **11,** 5, 426–433, Sept. 1960.

Paper investigates analytically the laminar-film condensation on a flat plate in the absence of any body force—as when the plate is placed horizontally in a gravitational field, or as in a nonrotating space vehicle. Equations are derived and shown graphically. G. G. Thurlow, England

5619. Vichnev, I. P., and Elukin, N. K., Heat transfer during the boiling of liquid in tubes (in Russian), *Inzbener.-Fig. Zb.* **3,** 5, 74–80, May 1960.

Paper presents experimental data on heat-transfer coefficients to boiling oxygen and nitrogen in natural circulation through circular pipes and at atmospheric pressure. The effect of l/d in the range 45–560 was investigated. Unfortunately (as in most Russian papers), the experimental apparatus and procedure are neither described nor discussed, thus limiting the value of the information. Nevertheless, the paper represents a significant contribution by stressing the importance and the effects of two-phase flow patterns on the heat-transfer coefficient. Authors conclude that when $l/d > 80$ the effect of the geometry and of the hydrodynamics must be taken into account. It appears to the reviewer than an l/d based on the boiling length instead of on the total length may be a more significant ratio.

The paper is part of a growing list of publications [Sachs, P. and R. A. K. Long, *Intern. J. Heat & Mass Transfer* **2,** 3, 222–231, 1961, among others] which bring up experimental evidence showing the effect of convection (forced or buoyant) and of the two-phase flow patterns on the heat transfer coefficient. It becomes evident that a considerable error can be made in estimating heat-transfer rates if these effects are neglected and the heat-transfer coefficient is computed from correlations based on nucleate pool boiling data alone, as proposed previously in the literature.
N. Zuber, USA

5620. Zozulya, N. V., A question of the procedure to be adopted when investigating the physical aspects of the process of heat emission when vapour is condensing (in Russian), *Sbornik Trudi In-ta Teploenerg., Akad. Nauk SSSR* no. 14, 32-42, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13732.

This is a methodical study having as its object the obtaining of reliable data for heat exchange when film condensation of vapor is taking place. The necessity for undertaking the study is not only the small quantity of data available but also the fact that such data basically refer to the condensation of water vapor at atmospheric pressure (when the study of the hydrodynamics of the film in the known experiments was not given any material value). A description is furnished of the experimental set-up and of the results of observations of the flow of the film forming on the vertical tubes of the condenser. The principal methodical features of the set-up and of the system of measurements adopted are: (1) the high degree of precision attained in the observation of the thermal regime and, in particular of maintaining the superheating of the steam with an accuracy of 1° (in the electrical system of heating of the boiler, automatic devices were used—contact thermometers, a mercury relay, autotransformers and so forth); (2) the extensive use of resistance thermometers for the obtaining of the mean temperature of the surface of the tube; (3) observations on the process of condensation with the aid of special mirrors. The apparatus was used on the regime for 5-6 hours. The testing of a single regime was carried out for 30 to 60 minutes. The coefficients of heat emission were measured with an accuracy of up to 5%. The vapor condensation of water and glycerine was investigated. The tests were made over a wide range of changes of temperature and pressure. As the result of the series of investigations made, it was established that in the upper part of the tube a laminar flow of the film takes place, followed by the formation on its surface, after the film had attained the determined thickness, of a spongy state passing over to ring-shaped waves. The value for Reynolds number R_* for the transition of the laminar flow to a wave flow is found

$$R_* = \frac{4\,q\,H}{r\,\gamma\,\nu} = 25\text{-}35 \qquad [1]$$

The following expression for the determination of the coefficient of heat emission is recommended:

$$\frac{\alpha_1}{\lambda}\left(\frac{\nu^2}{g}\right)^{1/3} = 1.05\,R_*^{-1/4}$$

Here q is the thermal tension of the surface of the condenser, H the height, r the latent heat of evaporation, γ the specific gravity of the liquid, ν the kinematic viscosity of the liquid, α the coefficient of heat emission, λ the heat conductivity, g the acceleration of the force of gravity. G. A. Varshavskii

Courtesy Referativnyi Zhurnal, USSR

5621. Babukha, G. L., and Nazarchuk, M. M., A method of calculation for the heat exchange in a two-phase vertical phase when the solid phase is in a polydispersion system (in Russian), *Dop. Akad. Nauk URSR* no. 7, 724-727, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13734.

When heating polydispersed solid materials in tubular driers it is important to take into account the different degrees of heating of particles of varying dimensions. For the calculation the authors propose to differentiate, in an imaginary sense, the polydispersion system in question by grouping into practically identical diameters d_i and to consider each of these fractions as moving independently along the tube at it own velocity of w_i. The degree to which this last proposition can be permissibly applied is not discussed by the authors. For each of these fractions an individual equation of motion is derived and its own equation for the thermal balance on a given element of the length of the tube dL. To this is added the equation of thermal balance for the ascending flow of the heating gas. The coefficients of resistance and heat emission for each of the fractions are investigated as assigned functions of the value of Reynolds' criteria. The initial velocity of the particles entering the lower part of the column is taken to be equal to zero. In the above conditions the authors propose to solve their system by the method of finite differences. O. M. Todes

Courtesy Referativnyi Zhurnal, USSR

5622. Test, F. L., The influence of bypass channels on the laminar flow heat-transfer and fluid friction characteristics of shell and tube heat exchangers, *ASME Trans.* **83** C (*J. Heat Transfer*), 1, 39-47, Feb. 1961.

Heat-transfer and pressure-drop data are correlated for laminar flow of SAE 60 oil through an 86-tube baffled shell and tube heat exchanger. Author uses effective area to correlate data. Several plots show that $h_0 \propto W^{0.75}$ and $\Delta P_T \propto W$. Quantitative effects of oil mean temperature and water mean temperature are presented graphically. Conclusion is drawn that bypass between shell and tube bundle significantly affects data as does viscosity of oil in contact with heat-transfer surface. On this basis pressure-drop equations are derived to predict nonisothermal ΔP for both baffled and unbaffled tube bundles. Equations agree with data within ± 20%. Heat-transfer correlation for cross-baffled units makes use of Prandtl number evaluated at mean oil temperature, viscosity ratios and effective Reynolds number based on effective cross flow area.

Correlations presented are empirical and not necessarily applicable to other configurations. J. G. Knudsen, USA

5623. Evnochides, S., and Thodos, G., Simultaneous mass and heat transfer in the flow of gases past single spheres, *AIChE J.* **7,** 1, 78-80, Mar. 1961.

Authors have measured the rate of evaporation of water and nitrobenzene from celite spheres 1.42, 1.88, and 2.00 inches in diameter immersed in an air stream at Reynolds numbers as high as 12,000. A constant relationship of the material and thermal transport parameters throughout the range of Reynolds numbers was found which was in agreement with other investigators in this field. The evaluation of the material transport parameters is based upon the assumption of perfect gases and ideal solutions.

Authors did not include comparison with other available experimental data upon the local and macroscopic material and thermal transfer from porous spheres at various levels of turbulence. Only limited comparisons of thermal transfer from spheres with and without material transport are presented. The results contribute to the background of experimental information concerning the macroscopic transport from single spheres under the conditions of simultaneous thermal and material transport.

B. H. Sage, USA

5624. Mikhailov, Y. A., Heat and mass transfer during rarefaction (in Russian), *Inzbener.-Fiz. Zb.* **4,** 2, 33-42, Feb. 1961.

Removal of water by vacuum desiccation procedes partly on a macroscopic scale; in addition water and other material are transmitted by diffusion-like processes and a considerable amount of heat is removed from the bodies to be desiccated to their surroundings. The rate of these processes is specified in terms of a set of simultaneous differential equations involving "potentials of filtration, mass transfer and heat transfer. With some simplifications these equations admit relatively simple solutions. Formulas are derived on the assumption that the body to be desiccated has the shape of an unbounded plate, or a cylinder or a sphere.

R. Eisenschitz, England

5625. Sergeyev, G. T., Heat and mass transfer during evaporation of liquid in a forced gas flow (in Russian), *Inzbener.-Fiz. Zb.* **4,** 2, 77-81, Feb. 1961.

Paper presents experimental data on heat and mass transfer by evaporation from water, acetone benzol and butyl alcohol to air in turbulent flow. The air Reynolds number was varied from 20×10^3 to 150×10^3, temperature from 20 to 200 °C, and moisture from 15 to 80%. Author concludes that the correlation proposed by Nesterenko [*Zh. Tekh. Fiz.* **24**, p. 729, 1957] is in good agreement with his experimental data. N. Zuber, USA

5626. Shashkov, A. G., The accuracy of measurement of temperature with thermistors (in Russian), *Inzhener.-Fiz. Zh.* **3**, 3, 123–125, Mar. 1960.

Attention is brought to the fact that precision of temperature measurements by means of thermistors depends on the accuracy of assessment of heat-transfer coefficient. A change of state of a medium results in a change in the heat-transfer coefficient and leads to an error in the temperature measurement. An expression is deduced for this error, and it is shown that with an increase of measurement precision the indicated error becomes commensurable with the basic error caused by the measured current, and therefore it should not be neglected.

S. Smoleniec, South Africa

5627. Swanson, B. W., and Somers, E. V., Refrigerator heat leak for sandwiched thermoelectric elements, *ASME Trans.* **83**C (*J. Heat Transfer*), 1, 102–104 (Tech. Briefs), Feb. 1961.

5628. Farztdinov, M. M., The measurement of the complex temperature field of walls subjected to convection heating (in Russian), *Inzhener.-Fiz. Zh.* **3**, 12, 11–16, Dec. 1960.

A method is given for calculating corrections introduced by a thermocouple in the course of temperature measurement. The problem is solved analytically and relationships given (26, 30, 31) with the aid of which the true value of temperature can be determined in individual cases. A method is also indicated by means of which the difference between readings and true temperature may be decreased. From author's summary

5629. Verzhinskaya, A. B., and Novichenok, L. N., A new universal method of determining thermophysical constants (in Russian), *Inzhener.-Fiz. Zh.* **3**, 9, 65–68, Sept. 1960.

The method consists in measuring the time-dependent temperature difference at two distances x_1 x_2 (usually $x_1 = 0$) from a surface at which at time $\tau = 0$ a constant heat flux has been suddenly applied. The known solution for a semi-infinite slab (one-dimensional flow of heat) is utilized, and the thermal diffusivity is calculated from the slope of Δt against $\tau^{1/2}$, the distance $x = x_2 - x_1$, and the heat flux $q_0 = \text{const}$.

The method was tried out in practice (on several solid materials), and the results appear to be satisfactory. The method is simple, if somewhat crude, but appears to be worth considering when no great accuracy is required and when recording potentiometers are available. The need to measure q_0 usually proves to be a drawback. J. Kestin, USA

5630. Shushpanov, A. P., and Shushpanov, P. I., A cylindrical heat source method for the determination of thermal constants (in Russian), *Inzhener.-Fiz. Zh.* **3**, 9, 74–77, Sept. 1960.

Paper contains a solution for the temperature field created in an infinite space by an instantaneous uniform line-source of length $2l$. The temperature in the plane of symmetry passes through a maximum in time, and the measurement of the instant at which this occurs can be utilized for the determination of the thermal diffusivity of the surrounding medium. If, in addition, the maximum temperature itself as well as the output of the heat source is measured, the product ρc of density and specific heat can also be determined. An analysis of some (but not all) errors is also given. The method is normally used for solids or insulating materials, but it would be interesting to investigate whether it could be adapted to liquids or gases, owing to the great attractiveness of its simplicity. J. Kestin, USA

5631. Iberall, A. S., Precise measurement of clothes insulation during controlled operation of the human, *ASME Trans.* **82** D (*J. Basic Engng.*), 3, 513–527, Sept. 1960.

It has been demonstrated that it is possible to measure the resistance of clothing as an ohmic relation between time-averaged equilibrium values of the flux of power (metabolism) and the potential difference between average skin temperature and ambient temperature. Specifically, this has been demonstrated on the human in what has been referred to as the comfort mode of operation of the human system. In this mode of operation, the metabolic level of activity is changed by signaling command to attempt to maintain a specific control level of the average skin temperature. With control attempted to approximately 0.1 deg C, sufficient precision has been achieved to resolve 1 or 2 per cent difference in clothes resistance. The dynamic input-output data obtained during clothes measurements are presented.

From author's summary

5632. Cutting, J. C., and Fay, J. A., High-heat-flux effects in wire heat gages, *J. Aerospace Sci.* **28**, 4, 342–343 (Readers' Forum), Apr. 1961.

Combustion

(See also Revs. 5179, 5586, 5592, 5732, 5733)

Book—5633. Herterich, O., Water as an extinguisher; application and technique for fire fighting [Wasser als Loeschmittel; Anwendung und Technik im Brandschutz], Heidelberg, Dr. Alfred Verlag GmbH, 1960, 236 pp. + figs. + tables DM 28.

This is a comprehensive treatise on all aspects of water—jets, sprays, and steam—which have some relation to fire fighting. It is organized under six main headings: properties of water; water jet; diffuse jet and spray; steam; extinguishing experiments; practical applications. Among the chapters falling within the scope of applied mechanics are: types of flow; pressure losses in pipes; waterhammer in conduits; free water jet and its characteristics; broken-up jet and spray and its characteristics; steam as extinguishing agent; fire-extinguishing experiments. Within this framework many aspects of the physics, mechanics, hydraulics, and engineering of water, jet, spray and drops are given a detailed, authoritative treatment. In particular, atomization, drop size, drops in free fall and in throw trajectory, surface area, energy of atomization, influence of pressure head, motion within the spray, impact force of spray, heat transfer to single drop, heat absorption and reflection, optimal drop size, production of jets and sprays by various nozzles, electric conductivity, and other topics, are dealt with in full detail.

This book represents a definite enrichment of the literature of fire fighting, and relieves future authors writing on this subject from repeating basic concepts, theories, and calculations. A very complete bibliography of 316 titles is included, most of which are discussed in the text, attesting to the thoroughness and painstaking research and search which went into the composition of this book, which merits a wide readership, and possibly a translation into English. K. J. DeJuhasz, USA

5634. Goldberg, S. A., Ignition in a flow (in Russian), *Inzhener.-Fiz. Zh.* **3**, 3, 28–35, Mar. 1960.

Theoretical study of ignition by incandescent bodies, flame stabilization by nonstreamlined-bodies and by a stream, in the frame

of a general theory [Khitrine, Seventh Int. Symp. on Combustion, London 1958] is refined by author by taking the boundary-layer theory into account.

Results seem to be in satisfactory agreement with some experiments (see also *ARS J.* **31**, 5, p. 691 (Russian Supple.), 1961).

N. Manson, France

5635. Cieplucb, C. C., Allen, H., Jr., and Fletcher, E. A., Ignition of solid propellant rocket motors by injection of hypergolic fluids, *ARS J.* **31**, 4, 514–518, Apr. 1961.

A preliminary experimental investigation was conducted to determine the feasibility of igniting soild propellant motors with hypergolic fluids. Ignition was accomplished by injecting a fluid into the propellant port, which upon contact reacted spontaneously with the fuel component of the propellant, providing sufficient heat for ignition and sustained reaction between the fuel binder and oxidizer. Motors containing composite and double-base propellant were ignited in this manner. Chlorine trifluoride was found to be the most effective ignition fluid, due to its superior reactivity.

From authors' summary

5636. Kozachenko, L. S., and Skachkov, G. I., Flame propagation in two and three component gaseous mixtures containing hydrogen, methane, nitrogen, and nitrous oxide (in Russian), *P.M.T.F., Zh. Prikl. Mekh. Tekh. Fiz.* **1**, 2, 93–99, 1960.

Results are discussed of measurements of normal burning velocities U_n measured at normal pressure and temperature. Most U_n values were obtained by burner method and some by constant pressure bomb with schlieren photograph method.

U_n values in mixtures with N_2O, lower than in corresponding N_2–O_2 mixtures, are probably conditioned by secondary reactions of N_2O in the burning zone.

An empirical formula for U_n maximum values is given as a function of the N_2 amount in the H_2–N_2O–N_2 mixtures.

N. Manson, France

5637. Senior, D. A., Burning velocities of hydrogen-air and hydrogen-oxygen mixtures, *Combustion and Flame* **5**, 1, 7–10, Mar. 1961.

A schlieren system for photographing the inner cone in bunsen flames used in burning velocity measurements is described. A useful magnification factor of 20 to 25 times measured from the burning cone to its photograph is obtainable; so the system can be used with the small burners needed for such fast burning flames as those of hydrogen-oxygen mixtures. Some results for hydrogen-oxygen and hydrogen-air flames are given which accord with Jahn's values at the lean end, though the results for the richer hydrogen-oxygen mixtures agree with the higher values determined by Bartholomé.

From author's summary

5638. Schalla, Rose L., Perturbation studies of flames by changes in composition, *Combustion and Flame* **5**, 1, 45–53, Mar. 1961.

The nature of perturbations created by abrupt changes in composition and their effects on flame propagation have been investigated for ethylene-air mixtures in a 1-in. square flame tube. The time required for the flame to establish a new linear velocity in a mixture of given composition and flame speed, after propagating through a preceding mixture of either higher or lower flame speed, was determined. When propagation was from a slow to a fast flame-speed mixture, oscillations in flame structure and velocity along with accompanying pressure disturbances were observed across the transition region. A small pressure decrease but no oscillatory behavior was observed for propagation from a fast to a slow flame-speed mixture.

From author's summary

5639. Eschenroeder, A. Q., Combustion in the boundary layer on a porous surface, *J. Aerospace Sci.* **27**, 12, 901–906, Dec. 1960.

The position of the diffusion flame in a boundary layer with uniform mixture injection from a porous wall parallel to a uniform air stream is determined under the conditions of laminar, steady flow with zero streamwise pressure gradient. Under the assumption of fast forward reaction rate, solutions of the boundary-layer forms of the conservation laws of aerothermochemistry are obtained leading to a formula for the downstream velocity at the flame in terms of composition and flow variables. The rates of change of conditions at the wall in the streamwise direction are assumed to be relatively small. Methods of treating complex reaction systems are described, and a generalized form of the Reynolds analogy is developed.

From the author's summary by W. T. Snyder, USA

5640. Firey, J. C., and Lavi, R. R., Shock waves from preflame reactions in a motored engine, *Combustion and Flame* **5**, 27–34, Mar. 1961.

Engine experiments with an impact pressure detector and a rate-of-change-of-pressure indicator demonstrate that preflame reactions are capable of generating impact pressures. Two-stage preflame reactions of normal heptane were observed with both stages developing impact pressures. It is proposed that these impact pressures are due to a shock wave formed by the preflame reaction and that this shock wave may lead to a detonation wave which is the compression ignition process.

From authors' summary

5641. Petrov, E. A., and Talantov, A. V., Procedure for determining the characteristics of combustion in a turbulent flow (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Aviats. Tekhn.* no. 1, 89–94, 1959; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13144.

A description is given of the procedure for determining the velocity of the propagation of the flame and the extent of the combustion zone along the lines of current for a stationary turbulent tongue of flame in a free flow (an "inverted" cone in the tube in section). The only requirement to carry out the calculations is to know the values of the inner boundaries of the "inverted" flame cone. The following assumptions were made: (1) The tongue of flame is situated in the open flow and consequently pressure in all the zones is identical and equal to the atmospheric. (2) The velocity of flow in all the zones is the same and equal to the velocity of the incoming flow. (3) The temperature in the combustion zone varies linearly in the transverse direction. The equation for the conservation of mass of the whole flow is considered to be the starting point for the derivation of the calculation correlationships. Results are given of the calculations for the velocity of the propagation of the flame, the extent of the combustion zone, the duration of combustion for a tongue of flame in the flow with a velocity of 40 m/sec and a coefficient for the surplus of air of $\alpha = 1.16$. A photograph of the tongue of flame taken with a camera "Zenit C" and exposure of 0.04 secs gave a good picture of the outer boundary of the tongue of flame and the angle of its opening out. The inner boundary of the flame was determined by CO^2 fields, using a GE UK-21-type gas analyzer. The measurements were made in a number of sections of the tube along the length of the tongue of flame.

V. P. Veselago

Courtesy Referativnyi Zhurnal, USSR

5642. Lebedev, B. P., and Tikhomirov, V. C., Experimental study of combustion of two-phase mixtures in turbulent flow, *Soviet Phys.-Tech. Phys.* **5**, 8, 929–937, Feb. 1961. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* 30, 8, 994–1005, Aug. 1960 by Amer. Inst. Phys., Inc., New York, N. Y.)

This paper gives the results of an experimental study of the characteristics of flame propagation and the length of the combus-

tion zone of a two-phase kerosene-air mixture in an open flame. The differences between the nature of the flame propagation in two-phase mixtures and in homogeneous mixtures were discovered. A study was made of the effect of different parameters of the mixture inflow on the turbulent flame velocity and the combustion time of the two-phase mixture. It was found that the flame velocity was affected most by the turbulence of the mixture inflow, including the additional turbulence due to injection of the fuel, and the mixture temperature. The combustion time depended mainly on the size of the fuel droplets and the temperature of the mixture.

From authors' summary

5643. Stradomskii, M. V., Investigation of the processes of mixing in the combustion chamber of a gas turbine working on natural gas (in Russian), *Sbornik Trudi In-ta Teploenerg. Akad. Nauk URSR* no. 16, 35–40, 1959; *Ref. Zh. Mekh.* no. 11, 1959.

Results are described of an experimental investigation of the distribution of the concentration of the burning gas in the sections of the combustion chamber of a gas turbine, the object being the determination of the intensity of the process of the mixing of the gas with the air. Natural (Dashavskii) gas was the fuel used in the chamber, the methane content being 98–99%. The relation of the concentration of the gas at a given point to its concentration in a stoichiometric mixture was taken as the characteristic of the degree of mixing. The measuring of the gas concentration was carried out by means of an automatic gas-analyzer in three sections along the length of the chamber while employing different quantities of air and gas delivered into the chamber. Some deductions were made, on the strength of the data obtained, regarding the intensity of the mixing of the gas and air; an empirical formula was also obtained characterizing the distribution of the concentrations of gas along the chamber's radius.

Yu. F. Dityakin

Courtesy Referativnyi Zhurnal, USSR

5644. Pawlowski, J., Combustion of a liquid droplet (in German), *Inter. J. Heat Mass Transfer* **2**, 1/2, 33–55, Mar. 1961.

Critical ignition and extinction processes in the burning of a liquid droplet floating in a turbulent atmosphere are mathematically discussed. The analytical-numerical investigation was carried out with the aid of the program-controlled computer IBM 650.

In the case of the model employed it is assumed that a single-step homogeneous reaction takes place in a narrow zone at rest in relation to the droplet and that the reactants are highly diluted with inert gas, so that the convective exchange (Stefan flow) can be neglected. The course of reaction is treated in a quasi-stationary manner. The critical ignition and extinction processes are discussed. The influence of the ten basic constants on the course of reaction, especially during the induction period, and on the ignition process, is discussed. For taking the convective exchange into account an iteration process is briefly described.

From author's summary by D. B. Spalding, England

5645. Tarifa, C. S., and del Notario, P. P. A theoretical investigation on the combustion of liquid bipropellant droplets, AFOSR TN-59-975 (Instituto Nacional de Tecnica Aeronautica Esteban Terradas, Madrid TN 1), 47 pp. + figs., Apr. 1960.

Assuming steady and symmetrical combustion, author derived differential equations of continuity, energy and diffusion over a liquid droplet (fuel or oxydizer) burning in gas phase (oxydizer or fuel). To solve the equations, a dimensionless coordinate X (= $(m/r) \times$ constant, where m = burning rate, r radial distance from a center of droplet) was introduced. Eigenvalue X_s ($= m/r_s$, r_s = radius of droplet) was calculated and graphically expressed in function of the parameter $\sqrt{A}r_s$ for various temperatures and compositions of the surrounding atmosphere. As A, a constant of chemical reaction rate equation, is proportional to n-th power of surrounding gas pressure when the chemical reaction is n-th order, $\sqrt{A}r_s$ will be represented by a product of gas pressure and droplet radius, pr_s, for the second-order reaction. Such graphs of X_s show that the widely admitted statement that m is proportional to r_s, obtained from the assumption of infinitely fast reaction rate, is verified only for large values of $\sqrt{A}r_s$ or pr_s, and m will be steeply decreased when the value of pr_s decreases to zero. The ratio of flame radius to droplet radius is constant for large values of pr_s, but, due to the calculation result, such ratio increases when pr_s decreases. This result agrees with the fact that the flame radius keeps a finite value even when r_s tends to zero. The thickness of the reaction zone also increases with decrease of pr_s.

These solutions, however, for the values of pr_s close to zero do not represent actual combustion process. Then, the author gave minimum value of pr_s under which combustion is not possible, as a function of the surrounding gas temperature and a dimensionless temperature θa (= (activation energy)/(heat of reaction) × constant). When the value of θa is large and surrounding gas temperature is low, not only the minimum value of pr_s is large, but also there mathematically exist three eigenvalues X_s in the region of medium values of pr_s. The above deduction suggests that there cannot be steady-state combustion and thereupon this theoretical treatment should not be applied in such a condition.

H. Jinno, Japan

5646. Ingebo, R. D., Size distribution and velocity of ethanol drops in a rocket combustor burning ethanol and liquid oxygen, *ARS J.* **31**, 4, 540–541, Apr. 1961.

Single jets of ethanol were studied photomicrographically inside a rocket chamber as they broke up into sprays of drops which underwent simultaneous acceleration and vaporization with chemical reaction occurring in the surrounding combustion gas stream. In each rocket test-firing, liquid oxygen was used as the oxidant. Both drop velocity and drop-size-distribution data were obtained from photomicrographs of the ethanol drops taken with an ultra-high-speed tracking camera developed at NASA, Lewis Research Center.

From author's summary

5647. Wanhainen, J. P., DeWitt, R. L., and Ross, P. S., Performance of a low-thrust storable-bipropellant rocket at very low chamber pressure, NASA TN D-678, 22 pp., Mar. 1961.

Characteristic exhaust velocities for the hydrazine and nitrogen tetroxide propellant combination were measured with triplet and two-on-two injectors in a nominal-50-pound-thrust uncooled combustion chamber at a chamber pressure of approximately 10 pounds per square inch absolute. Steady-state performance is presented for a range of oxidant-fuel mixture ratios from 0.7 to 1.2. Peak characteristic exhaust velocity obtained was 5280 feet per second or approximately 92% of the theoretical value.

From authors' summary

5648. Lyakhovskii, D. N., and Anosimova, E. N., The aerodynamics of combustion chambers of square section with the burners arranged tangentially (in Russian), *Energomashinostroenie* no. 2, 16–22, 1959; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13364.

Descriptions are given of the results of experimental investigations on the flow of air in a combustion chamber with the burners arranged in a tangential pattern. The problem to be surmounted was an attempt to gage the aerodynamic characteristics of the chamber against its structural parameters (the relation of the dimensions in plane, the relative height, the relation of the areas of the total sections of the inlets and of the transverse sections of the chamber and outlet, etc). The procedure used and the structural details are described for a transparent combustion chamber with angularly set burners. Drawings are furnished of the flow in the

chamber and graphs of the dimensionless velocities in sections of the model of the chamber. On the basis of the data obtained some deductions are drawn regarding the influence of the constructional parameters on the picture presented by the flow. It was established that with a tangential arrangement the aerodynamic axes of the tongues of flame deviate at a sharp angle to the geometrical axis of the burners ("adhesion" of the tongues of flame to the walls). It is indicated further that this phenomenon may be the reason for the soot formation on the walls of chambers with tangentially disposed burners set in the lateral walls. Recommendations are given for the rational selection of dimensions for a combustion chamber with tangentially arranged burners.

Yu. F. Dityakin
Courtesy Referativnyi Zhurnal, USSR

5649. Hersch, M., Combined effect of contraction ratio and chamber pressure on the performance of a gaseous-hydrogen-liquid-oxygen combustor for a given propellant weight flow and oxidant-fuel ratio, NASA TN D-129, 13 pp., Feb. 1961.

A combustor of about 150 pounds thrust was used to determine the characteristic exhaust velocity. The contraction ratio was varied from 1.5 to 6, with a resultant chamber pressure variation of about 25 to 120 lb/sq in. Experimental performance was about 98% of theoretical at contraction ratios above 3 and chamber pressures above 60 lb/sq in. Below these values, performance decreased rapidly. An analytical investigation using a mixing model and a vaporization model indicated that low performance at low contraction ratios and chamber pressures might be caused by poor gas-phase mixing due to low turbulence conditions.

From author's summary

5650. Kling, R., and Brulard, J., Study of the combustion of composite powders with the help of ultra-rapid microphotography (in French), *Rech. Aéro.* no. 80, 3-11, Jan./Feb. 1961.

5651. Richards, J. H., Griffiths, D. K., and Sidwell, C. W., Application of aerodynamic design to the "U-fired" soaking pit, *J. Iron Steel Inst., Lond.* **197,** 2, 117-121, Feb. 1961.

The "U-fired" soaking pit, of a regenerative type, was designed for the combustion of blast-furnace gas. The regenerators with ejector-type stacks outside the building structure conserved limited building space and facility requirements. A laboratory investigation in which flow models were used to study the aerodynamic characteristics of the design showed a favorable flow pattern insensitive to ingot placement. Operation of a mock-up pit constructed by modifying two neighboring through-fired soaking pits confirmed the flow-model evaluation, with small differences in ingot temperature and a small pit-time/track time ratio. Investigations of a modified U-fired soaking pit by means of flow models demonstrated the dependence of flow pattern on firing-port size and burner design. Present operation of the U-fired soaking pits are described.

From authors' summary

5652. Batten, J. J., A possible error in the measurement of rate constants of gaseous reactions by flow techniques, *Austral. J. Appl. Sci.* **12,** 1, 11-22, Mar. 1961.

In the interpretation of kinetic measurements of chemical reactions performed in flow systems in which a tubular reactor equipped with narrow inlet and outlet tubes has been employed, it has usually been tacitly assumed that plug flow has existed throughout the whole volume of the reactor, under all experimental conditions. To test the validity of this assumption, experiments were designed to determine the nature of the flow pattern developed within such reactors. These experiments have shown, contrary to the above assumption, that under a wide range of experimental conditions, the bulk of the gas flows through the reactor without diffusing laterally to any appreciable extent. This observation throws considerable doubt on the interpretation of all published kinetic measurements obtained under similar experimental conditions, where the results have been calculated assuming that plug flow has existed throughout the length of the reactor.

From author's summary

The following four papers describe the first two trials of the International Flame Research Foundation on pulverized-fuel firing, *J. Inst. Fuel* **33,** no. 235, Aug. 1960.

5653. Thurlow, G. G., Summary of work carried out, *J. Inst. Fuel* **33,** 235, 366-376, Aug. 1960.

This is the first in a series of four papers on research on pulverized-fuel flames in a furnace employing an axial primary jet surrounded by an annular secondary jet. The paper describes the experimental plant including coal preparation furnace design, and description of measurements made including:

(1) Velocity by pitot tube measurements
(2) Gas temperature using suction pyrometers
(3) Gas analysis
(4) Solid-particle concentration
(5) Wall and roof temperature using thermocouples
(6) Waste-gas temperature using suction pyrometer
(7) Narrow angle radiation measurements of the flame refractory background

Summary temperature, composition, and velocity contours in the flame and flame radiation data are presented. Carbon formation as a function of position and mixture ratio and distance from burner is also presented. These quantitative data are used to attempt to describe how pulverized fuel particles behave in a flame under a variety of conditions.

D. M. Mason, USA

5654. Tissandier, G., Cold aerodynamic trials on a fifth-scale model of the Ijmuiden pulverized-fuel furnace, *J. Inst. Fuel* **33,** 235, 377-385, Aug. 1960.

A fifth-scale cold model of a commercial pulverized-coal furnace was made with air flowing in both the axial and annular jets, air flow rates being the primary variable. Two burners of different dimensions to give widely different primary and secondary jet areas were included. Axial velocities were measured with a pitot tube and the results were analyzed employing dimensional analysis. Of importance in the velocity ratios is a reference velocity, $U^+ = (G_t/\rho S)^{\frac{1}{2}}$ where G_t is the total momentum of the jet, ρ the mean density of the jet, and S the cross section of the furnace. Experimental plots of dimensionless ratios are presented and it is found that a generalized reduced curve fits the data for both burners.

D. M. Mason, USA

5655. Hubbard, E. H., The first performance trial and first combustion mechanism trial with pulverized coal, *J. Inst. Fuel* **33,** 235, 386-399, Aug. 1960.

This paper discusses in detail the measurements made on the pulverized-coal furnace summarized in part 1 [Rev. 5653]. Interpretation of the detailed data leads to the following conclusions:

The general velocity and concentration profiles and recirculation distribution are found to be qualitatively similar for this primary-secondary jet device and a single jet device. The data show that on entering the furnace 95% of the volatile constituents are formed in 50 milliseconds. Combustion is assumed to take place very rapidly so that the turbulent mixing of air and fuel controls the process. The pulverized-fuel flame was found to have an emissivity approaching unity for over half its length.

D. A. Mason, USA

5656. Alpern, B., Courbon, P., Plateau, J., and Tissandier, G., Microscopic examination of samples taken from a pulverized-fuel flame, *J. Inst. Fuel* **33,** 235, 399-402, Aug. 1960.

Solid samples were withdrawn from various positions in a pulverized-coal furnace and subsequently examined microscopically, employing an electron and an optical microscope. The size distribution of particles was also determined. The techniques enable one to identify original coal particles, eroded cenospheres, and the appearnace of carbon black by cracking of the volatile matter.

D. M. Mason, USA

Prime Movers and Propulsion Devices

(See also Revs. 5539, 5577, 5646, 5724, 5728, 5730, 5734)

5657. Schaffitz, W., and Schley, W., Crank angle marking device for simplifying the indicating of engines (in German), *Motortech. Z.* **22,** 5, 169–172, May 1961.

If a light-flash stroboscope is triggered, by means of a suitable pickup, from a rotating shaft (crankshaft or camshaft of an engine), then the stroboscope can be used to illuminate the shaft, or flywheel, always in the same phase (e.g., the dead center) of rotation, and the crank-angle position can be read on the graduation of the flywheel. Using the same triggering impulse in a suitable manner, it is possible also to obtain on the oscillographic record of a certain variable (e.g., cylinder pressure) of the engine, a mark such as a gap or interruption on the oscillogram. In this manner the value of the variable, and the crank angle at which it occurs, can be accurately correlated. This principle, and its actual realization, are discussed and explained in detail, with a sketch of the general arrangement, and the error sources involved, such as the time delay (about 5 microseconds). The complete equipment is shown (made by Vibrometer A.-G., Fribourg-Moncor, Switzerland), and some examples, such as injector needle lift, cylinder pressure, and pressure rise, are given. It is pointed out that often it is not necessary to photograph the oscillograph light trace; simple observation and data taking (correlated crank angle and peak pressure, etc.,) suffice for the test.

This is a simple and straightforward experimental procedure which should be adequate for many research purposes on internal combustion engines and other piston machines.

K. J. DeJuhasz, USA

5658. Foldi, T., Acceleration of automotive vehicles (in Hungarian), *Járművek Mezögazdasági Gépek* **8,** 3, 82–85, Mar. 1961.

Author discusses the problems of acceleration of motor vehicles, mainly from the point of view of optimal conditions as regards economy and time for traveling a given distance. He treats the motion as a function of time, of acceleration, and of initial velocity. Based on the differential equation of accelerated motion, expressions for distance traveled are derived for given values of: (1) acceleration, (2) time, (3) initial velocity, the other two quantities being used as parameters or independent variables. The relationships thus found are represented also in graphs and tables. The results are interpreted from the aspect of time saving, and excess (or reserve) of acceleration. Author finds that for time saving the initial velocity may be more important than a large reserve of accelerating force.

K. J. DeJuhasz, USA

5659. Pflaum, W., and Reiher, D., Selection and influence of various gases on gas turbines with nuclear reactors (in German), *Jahrbuch Schiffbautech. Gesellsch.* **53,** 116–137, 1959.

Influence of working fluids (N, He, Ne, H, D, O, Co_2) in closed nuclear reactor-gas turbine cycle is systematically analyzed. System consists of gas-cooled reactor, turbine generator, heat exchanger, cooler, compressor. Over-all cycle and component characteristics are presented in detail. Turbine and compressor flow, rpm, number of stages, blade length and diameter are given for each working fluid, based on typical general assumptions. Specific results are presented for 3MW output and 700°C turbine inlet temperature.

Best choice of working fluid is admittedly a compromise. Some chemical reactions with structural materials and in radiation environment are insufficiently known to be fully evaluated. Authors favor He.

R. P. Kroon, USA

5660. Berman, K., and Crimp, F. W., Jr., Performance of plug-type rocket exhaust nozzles, *ARS J.* **31,** 1, 18–23, Jan. 1961.

Authors discuss advantages of plug-type nozzles—in which all or part of the supersonic expansion occurs external to the nozzle—for rockets. Basic equations for Prandtl-Meyer flow configuration are summarized. Experimental data confirm that below design pressure ratio the plug nozzle has greater thrust coefficient than the conventional nozzle. Replacing a portion of the Prandtl-Meyer plug shape by a cone results in a much shorter nozzle with almost the same efficiency.

Other advantages indicated by the authors: Combined with an annular combustor the plug nozzle makes thrust vector control possible by varying the pressure in the combustor sectors; the use of a movable plug permits chamber pressure and thrust control, which can serve to program thrust as a function of time for greater range and safety.

R. P. Kroon, USA

5661. Sternin, L. E., On the analysis of an axially-symmetric nozzle of minimum weight (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 1, 41–45, Jan./Feb. 1959.

Author develops analytical relationships for the determination of the optimum geometrical characteristics of a jet nozzle. Variational methods are used for the solution of the equations. No spectacular results have been obtained. Bibliography includes only three fairly old Russian publications of a general character.

G. A. Tokaty and D. J. Huggett, England

5662. Sarner, S. F., and Dollries, J. F., An integrated propellant performance analysis program, *ARS J.* **31,** 2, 257–258 (Tech. Notes), Feb. 1961.

Note describes a computer program for performance of propellant systems in rocket motors. Authors provide for various assumptions regarding chemical equilibrium, multiple phase products, with various combinations of velocity and thermal lag between phases. Program provides for complete print-out of results in report form using IBM-704 and IBM-7090 computers. Compared to many similar programs reported in the past three years, this one seems relatively versatile. Details in the note do not establish rigor of the theory on which program is based but, at worst, this program would be an excellent tool for screening the potential of untested propellant systems and estimating the importance of lag processes.

E. W. Price, USA

5663. Greiner, L., Selection of high performing propellants for torpedoes, *ARS J.* **30,** 12, 1161–1163, Dec. 1960.

Author shows that energy per unit volume is of most importance in evaluating propellants for torpedoes. Considering the chemical performance of a number of fuel and oxidizer combinations and limiting combustion temperatures to 1800°F by free water diluent, the author shows in a table of 21 fuel and oxidizer combinations that aluminum or zirconium reacting with the free water give the highest theoretical energy releases per unit of volume. He considers briefly the ways in which the reactions between the metal and the water can be initiated and maintained.

F. E. Reed, USA

5664. Arens, M., A hypersonic ramjet using a normal detonation wave, *Bull. Res. Council Israel* 8C, 1, 35–46, Feb. 1960.

Author derives theoretical relations governing performance of ramjet with supersonic velocity entering the combustor, having a normal detonation wave in the combustor. Engine performance, based on perfect component efficiencies, is presented for flight Mach numbers of 6 to 10. R. P. Kroon, USA

5665. Garner, N. R., Hartvigsen, D. E., and Vail, R. W., Jr., Experimental designs for rocket motors, *Aero/Space Engng.* **20,** 3, 12-13, 32, 34-36, Mar. 1961.

5666. Factors that affect operational reliability of turbojet engines, NASA TR R-54, 211 pp., 1960.

The report discusses problems of operational reliability for turbojet engines. Data supplied by the military services were statistically analyzed. Studies were based on maintenance records and on flight accidents. Causes for component failures were grouped under: (1) Underdesign and defects in materials and manufacture; (2) Wear; (3) Creep; (4) Fatigue; (5) Foreign-object damage; (6) Overtemperature and overstress; (7) Thermal distortion and thermal fatigue; (8) Corrosion and stress-corrosion; (9) Fuel-control malfunctions. Their effect on reliability were studied and evaluated. Foreign-object damage has been found to be the principal cause of failures or flight accidents. Operational reliability can be improved by: (1) Design; (2) Inspection in manufacture; (3) Inspection in service; (4) Replacement schedules; (5) Records; (6) Operational and repair practices. Additional information needed to improve operational reliability is listed.

The report supercedes NACA Research Memorandum E55H-2 by Lewis Laboratory Staff, 1956. J. Koziarski, USA

Book—5667. LeGalley, D. P., edited by, Propulsion and auxiliary power systems, Vol. 2 (Proceedings of the Fifth Symposium on Ballistic Missile and Space Technology, Los Angeles, August 1960), New York, Academic Press, 1960, x + 441 pp. $9. (Revs. 5667-5682)

5668. Mascis, R. J., Application of the density ratio method for the interpretation of radiographic film of large solid propellant rockets, 3-54.

5669. Ritchie, D. J., Soviet rocket propulsion, 55-85.

5670. MacPherson, A. H., A discussion of several criteria for determining the propellant bias for optimum performance of liquid propellant stages, 87-109.

5671. Powers, C. S., Precision determination of vacuum specific impulse from trajectory data, 111-126.

5672. Krohn, V. E., and Shelton, H., Charged metal droplets for propulsion, 129-136.

5673. Singer, S., A versatile ion source for propulsion, 137-157.

5674. DeGroff, H. M., Halverson, W. D., and Holmes, R. A., Electrogasdynamic analysis of ion jet neutralization, 159-182.

5675. Georgiev, S., Feinberg, R., and Janes, G. S., A pulsed plasma accelerator employing electrodes, 183-201.

5676. Cook, J. C., Electrostatic lift for space vehicles, 203-241.

5677. LaRocca, A. V., Parametric performance studies of electrical thrust generators for space applications, 243-299.

5678. Colucci, S. E., Experimental determination of solid rocket nozzle heat transfer coefficient, 303-343.

5679. Anderson, F. D., Cockeram, D. J., Dieckamp, H. M., and Welch, J. R., Nuclear space power—Snap II, 347-372.

5680. Ross, D. P., Ray, E., Rapp, E. G., and Taylor, J. E., A one-megawatt nuclear electrical power plant for space applications, 373-382.

5681. Shoun, C. W., Bleed gas from a solid propellant rocket engine to power an auxiliary power supply, 383-408.

5682. Harvey, R. J., and Hatsopoulos, G. N., Isotopic fueled thermionic generators, 409-441.

Magneto-fluid-dynamics

(See also Revs. 5230, 5447, 5554, 5675, 5733)

5683. Chekmarev, I. B., On the quasi-one-dimensional steady flow of a compressible conducting gas in a pipe of constant cross-section in the presence of transverse magnetic and electric fields, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24,** 3, 801-803, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N.Y.)

Equations for steady one-dimensional compressible flow of a conducting ideal gas are integrated for the case of mutually perpendicular electric field, magnetic field, and flow direction. Electric field is assumed proportional to magnetic field. Results include an implicit relation for velocity, the distorted magnetic field as a function of velocity and the thermodynamic state variables. Author does not discuss results, nor are any graphs presented. Application to power generation or nozzle flow is possible; however much work remains to interpret results.

Mary F. Romig, USA

5684. Murty, G. S., Instability of conducting fluid cylinder due to axial current (in English), *Arkiv for Fysik* **18,** 3, 241-250, 1960.

Author considers the stability, against sinusoidal perturbations of the boundary, of an infinite, circular cylinder of inviscid, incompressible, weakly conducting fluid, e.g., mercury. Current is assumed flowing along the cylinder in the axial direction. No other magnetic fields are present. Under surface tension and magnetic forces alone calculation of all quantities in the dispersion relation can be accomplished and a range of perturbation wavelengths is found for which the cylinder is unstable. Surface tension stabilizes, whereas current de-stabilizes. Comparison with previously published experiments shows the theoretical values to be consistently low. This is attributed mainly to possible overestimation of the actual surface tension and to the neglect of the effects of vertical fall under gravity. Effect of gravity is approximately treated and shown to have a de-stabilizing influence near the orifice. F. D. Bennett, USA

5685. Stewartson, K., On the motion of a non-conducting body through a perfectly conducting fluid, *J. Fluid Mech.* **8,** 1, 82-96, May 1960.

Author shows for the title problem that the usual form of small perturbation theory for the flow about thin airfoils, e.g. as developed by Sears and Resler [*J. Fluid Mech.* **5,** 257-273, 1959; AMR **12**(1959), Rev. 5255], is not valid as it leads to a contradiction. However, the difficulty vanishes if the Alfvén velocity greatly exceeds fluid velocity. Author studies this case which holds for bodies of general shape and shows that the disturbance extends to infinity inside planes which touch the body and are

parallel to the undisturbed magnetic field, and that as a consequence the body experiences a drag force.

Reviewer believes the paper to be a valuable contribution to the subject, although some account of the applicability of the theory to a real problem in physics would enhance its values.

L. C. Woods, England

5686. Hasimoto, H., Steady longitudinal motion of a cylinder in a conducting fluid, *J. Fluid Mech.* **8,** 1, 61–81, May 1960.

The steady motion of an infinitely long solid cylinder parallel to its length in a conducting viscous fluid in the presence of a uniform magnetic field is studied. Alfvén waves originating at the cylinder produce two opposite "wakes" parallel to the applied magnetic field.

Formulas are derived for the viscous and magnetic drags and exact solutions are obtained for the case of a perfectly conducting or an insulating flat strip of semi-infinite width.

L. C. Woods, England

5687. Poots, G., and Sowerby, L., Axially symmetric stagnation point flow with heat transfer in magnetohydrodynamics, *Quart. J. Mech. Appl. Math.* **13,** 4, 385–407, Nov. 1960.

The steady axially symmetric stagnation point flow produced by a parallel stream which moves perpendicularly toward a wall is studied with the assumption that the fluid is incompressible but viscous and electrically conducting and that a magnetic field normal to the thermally insulated wall is present. All material constants of the flow are assumed to be independent of the temperature and the strength of the magnetic field. The result of the magnetohydrodynamical investigations is that one can distinguish three different regimes of flow: a magneto-viscous layer analogous to the ordinary boundary layer of hydrodynamics near the wall in which viscous and Lorentz forces are important, the potential flow regime in the free stream where the velocity field is directly proportional in strength to the magnetic field, and an intermediate magneto-inviscid buffer layer in which viscosity is unimportant but the Lorentz force remains comparable in magnitude with the inertia terms.

A particular case of the parameter values is numerically discussed in detail by means of a series expansion in terms of the magnetic parameter. For reference, detailed tables are included. It turns out that the magnetic field considerably reduces, in the vicinity of the stagnation point, the local shear stress and the eigentemperature at the wall. F. Engelmann, France

5688. Chekmarev, I. B., On the unsteady flow of an incompressible viscous conducting fluid in a halfspace in the presence of a transverse magnetic field, *Soviet Phys.-Tech. Phys.* **5,** 8, 865–869, Feb. 1961. (Translation of *Zh. Tekh. Fiz., Akad. Nauk SSSR* **30,** 8, 920–924, Aug. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

The unsteady flow of a conducting fluid which fills the halfspace over an unbounded infinitely thin moving plate is examined. The lower halfspace is considered to be filled with an immovable solid conductor. There exists an external magnetic field. Transforms of the unknown functions are found with the help of the Laplace transformation, for an arbitrary motion of the plate.

For particular ratios of the parameters simple solutions in closed form are obtained for uniform and oscillating motion of the plate. From author's summary

5689. Bhatnagar, P. L., Vorticity and circulation in a compressible viscous flow in the presence of magnetic field, Indian Inst. Sci. (Golden Jubilee Res. Vol. 1909–1959); 1959, 194–199.

Situations are derived under which the irrotational character and circulation are preserved in a motion of a compressible viscous fluid in the presence of a magnetic field.

From author's summary by D. C. Leigh, USA

5690. Lehnert, B., On the confinement of charged particles in a magnetic field, *J. Nuclear Energy, Part C. (Plasma Phys., Accelerators, Thermonuclear Res.)* **1,** 1/2, 40–48, Oct. 1959.

The rôle of a ring-shaped solid conductor placed in the interior of a plasma and producing a strong poloidal magnetic field, which has been suggested by the author earlier [Lehnert, B. *Nature* **181,** p. 331, 1958] in order to improve the confinement of the plasma, is discussed in detail in the framework of the individual particle model and using Alfvén's perturbation theory. It can be shown that the drift motions form closed paths around the symmetry axis of the loop so that a complete trapping is achieved. Further discussions concern the most favorable arrangement of the leads which supply current to the conductor, modifications and improvements of the magnetic field configuration by the addition of auxiliary coils, injection of ions into the confinement volume and other possible heating mechanisms, and, finally, the stability problem.

F. Engelmann, France

5691. Colgate, S. A., Collisionless plasma shock, *Physics of Fluids* **2,** 5, 485–493, Sept./Oct. 1959.

The structure of an extremely strong magnetohydrodynamic shock is discussed in the limit of no particle collisions. It is tentatively concluded that the shock transition takes place through mechanism of a strong electric field produced by charge separation. The pressure in the shocked plasma is due primarily to a very high electron temperature. The entropy increase occurs by Landau damping of the coherent electron oscillation. The ions, on the other hand, undergo an irreversible temperature change of only 3. From author's summary

5692. Fainberg, Ya. B., Non-linear theory of slow plasma waves, *J. Nuclear Energy, Part C. (Plasma Phys., Accelerators, Thermonuclear Res.)* **1,** 3, 153–157, Mar. 1960.

The propagation of electromagnetic waves in a narrow plasma waveguide is examined in a nonlinear approximation. The dependence of the phase velocity on the amplitude is derived, and consideration is given to the problem of frequency multiplication. The amplitude of the second harmonic is calculated. Owing to nonlinear effects a new possibility arises of varying the phase velocity of the wave by means of a variation of the amplitude and of insuring radial and phase stability in accelerators and also of of a certain modification of the methods of amplifying and generating micro-radio waves.

From author's summary by A. E. Bryson, USA

5693. Kaufman, A. N., Plasma viscosity in a magnetic field, *Physics of Fluids* **3,** 4, 610–616, July/Aug. 1960.

The viscosity of a fully ionized plasma in a magnetic field is analyzed from two points of view: first, from a consideration of particle orbits: and second, from the solution of a simplified Boltzmann equation. These semiquantitative methods are studied in order to clarify the behavior of the viscosity coefficients.

From author's summary

5694. Meckel, B. B., and Harkins, P. A., Production and analysis of a large-diameter plasma beam, *J. Appl. Phys.* **32,** 3, 489–493, Mar. 1961.

A continuously operating low-velocity plasma accelerator is described which has a beam diameter of 3.6 cm. The beam is produced by extracting ions from a discreetly generated singly charged ion plasma in the following manner: A fine wire mesh placed so that one side is exposed to the plasma acts as a solid flat cathode when given a negative potential. Some of the ions which are attracted to the mesh pass between the wires and stream into the region behind the mesh where they enter a field of thermionically emitted electrons. The resulting beam consists of a stream of parallel-flowing ions with a compensated negative

space-charge atmosphere of randomly moving electrons. Beam densities of 2×10^8 ions/cm^3 of 100-ev Hg^+ ions are obtainable 15 cm from the extractor. Gas pressures are maintained which provide mean free paths which are long compared to the tube dimensions. The diagnostic techniques used to analyze the beam parameters are described. The system is versatile and may be altered to permit the use of other gases, pressures and ion velocities. From authors' summary

5695. Josephson, V., Superfast pinch experiment, *Physics of Fluids* **3,** 6, 1001–1007, Nov./Dec. 1960.

An assembly designed to accelerate deuterons to about 10 kev by means of a radially converging magnetic piston has been constructed and tested. The assembly operates with 300 kv on the energy storage condenser, the ringing frequency is 18 Mc, and present operation uses hydrogen gas at 50 μ. Both slow and fast pinches have been observed, the former being possibly thermal shock waves, and the latter possibly being associated with inward motion of the plasma sheath.

From author's summary

5696. Colgate, S. A., and Furth, H. P., Stabilization of pinch discharges, *Physics of Fluids* **3,** 6, 982–1000, Nov./Dec. 1960.

The hydromagnetic stability properties of "hard-core" pinches are shown to be more favorable than those of conventional "stabilized pinches." Linear "hard-core" pinch experiments with a wide range of configurations show a basic consistency with hydromagnetic theory, but all configurations studied so far become unstable at sufficiently high current densities and low particle densities, even if possessed of theoretical hydromagnetic stability. Pinches with nulls in B_θ tend to be much less stable than those with nulls in B_z. "Inverse stabilized pinches" yield perfectly reproducible magnetic probe traces at power levels several times those at which "stabilized pinches" are unstable. A technique for the study of plasma density distributions is given, based on the propagation of radial compressional waves. The theory of the steady-state pinch is enlarged to include convective effects and is documented by experiment. The role of electrodes is considered, and an anode-cathode asymmetry in instability behavior is demonstrated for the linear "stabilized pinch." The prospects of stable, high-temperature operation with the toroidal hard-core pinch, or "levitron," are discussed.

From authors' summary

Aeroelasticity

5697. Makhortykh, Zh. K., Vibrations of a two-span panel in gas flow (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **28,** 51–54, 1960.

Linear flutter of a two-span panel when subjected to a gas flow with constant velocity is considered. Simply supported panel is strengthened by a rib perpendicular to direction of gas flow. Author concludes that when the rib is placed in the middle line of the panel a significant increase of critical velocity occurs. References are made to other Soviet papers on the same subject.

K. Pisczek, Poland

5698. Bolotin, V. V., Nonlinear flutter of plates and shells (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **28,** 55–75, 1960.

Nonlinear flutter of flat and curved plates in supersonic stream is investigated. A. Ilyushin's formula and piston theory (H. Ashley, C. Zaratarian) serve as basis. Mid-surface tension and bulging due to aerodynamic heating are taken into account. Boundary conditions are selected to account for combined behavior of panel and structure. Author observes that increase in critical flutter velocity in many instances does not indicate immediate panel failure which may be delayed and may develop fatigue characteristics. In some instances nonlinearity allows detection of prohibitive, self-exciting vibrations for speeds lower than critical flutter. Author begins with rectangular, singly curved panel in supersonic stream of undisturbed velocity parallel to straight edges. Kirchoff-Love's hypothesis is assumed. Panel's deflections are in order of thickness and small compared with edges. Flutter motions are assumed sufficiently small so only normal inertia forces are involved. Curvilinear coordinates along lines of curvature of undeformed mid-surface are employed, and stress function is introduced. Temperature variation is linear through the thickness and arbitrarily changes depending upon planform's position coordinates.

Proposed system of equations appears markedly simple. Thermo-bulging and flutter-of-bulged-panel problems appear as two distinct types. V. A. Valey, USA

5699. Rodden, W. P., and Albert, R. S., On the inclusion of engine effects in a flutter analysis, *J. Aerospace Sci.* **28,** 2, 167–168 (Readers' Forum), Feb. 1961.

Three effects are considered: the gyroscopic coupling of the rotor, the engine-intake effect, and the Coriolis damping from flow through the engine. Author concludes that for normal configurations the intake effect is destabilizing and the gyroscopic effect can cause adverse coupling, but that these effects are small.

J. G. Eisley, USA

5700. Molyneux, W. G., Approximate formulae for flutter prediction with particular reference to main surface flexure-torsion flutter in the transonic region, *Aircr. Engng.* **32,** 382, 356–362, Dec. 1960.

An approximate formula for the flutter speed of a binary system is developed on the basis of simplifying assumptions, the principal one stemming from the observation that dynamic pressure at flutter is approximately independent of air density. Since the formula includes flutter coefficients, additional assumptions are made to reduce it to a more practical form, but these limit its applicability to specific cases. Aerodynamic stiffness derivative data are required, preferably for unsteady flow, although steady flow data can be used with some reduction in accuracy. The method is less empirical than previously proposed approximations, and consequently offers the prospect of greater precision.

G. Isakson, USA

5701. Shveiko, Yu. Yu., Stability of circular cylindrical shells in gas flow (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Mekh. i Mash.* no. 6, 74–79, Nov./Dec. 1960.

The critical flutter speed is computed for an elastic cylindrical shell of finite length (concrete solution is given for the case of supported ends) in a transonic gas flow parallel to the longitudinal axis. Axial prestressing is not assumed.

The gas pressure has been determined by the piston theory. The derivation of the critical speed includes the damping effect. The deformation components are approximated by four members to the maximum corresponding to the first four natural modes of vibration.

The results show that for practical use damping and tangential components of inertia forces can be neglected and that there is no need to consider in the deformation expressions more than the first two members.

The modes of vibration, corresponding to the minimal critical flutter speed, have at least six waves along the circumference. With increasing damping the critical Mach number also increases, but the wave number decreases a little.

No experimental results are given.

V. Petrovsky, Czechoslovakia

5702. Weaver, W., Jr., Wind-induced vibrations in antenna members, *Proc. Amer. Soc. Civ. Engrs.* **87,** EM 1 (*J. Engng. Mech. Div.*), 141–165, Feb. 1961.

Using results of wind-tunnel tests on circular aluminum tubular members, author obtains a curve for the RMS von Karman lift coefficient in the range of Reynolds numbers from 10^4 to 10^6 and establishes a semi-empirical means for evaluating the effect of self-amplification. The effectiveness as spoilers of small-diameter tubing wound in a helical pattern over the surface of the members was also tested and optimum spoiler diameters and configurations determined. F. L. DiMaggio, USA

5703. Jones, J. P., The torsional oscillations of airscrew blades at low mean incidences, Aero. Res. Counc. Lond. Rep. Mem. 3177, 13 pp., 1960.

An attempt is made to explain the observed torsional oscillations of an airscrew by means of the "wake" theory. It is shown that the aerodynamic torsional damping becomes negative at certain blade angles and frequencies; the frequencies, or speeds, at which a single blade becomes unstable are shown to differ slightly from the critical frequencies of a multi-blade airscrew. At low incidences it does not appear to be possible to completely avoid this type of oscillation, but it is suggested that the oscillatory stresses might be reduced by moving the flexural axis toward the leading edge.

From author's summary by G. Isakson, USA

Aeronautics

(See also Revs. 5406, 5448, 5506, 5551, 5607, 5664, 5700, 5703, 5716)

5704. Rogerson, G. E., Estimation of take-off and landing airborne paths, *Aircr. Engng.* **32,** 381, 328–331, Nov. 1960.

Two types of maneuver, in one of which lift coefficient and excess thrust are constant, and in the other of which speed is constant, are analyzed. The analysis leads to simple methods of estimating take-off and landing airborne paths.

From author's summary by H. Merbt, Germany

5705. Robinson, R. B., Aerodynamic characteristics in pitch and sideslip of a 1/15-scale model of the Scout vehicle at a Mach number of 2.01, NASA TN-D-793, 37 pp., May 1961.

An investigation has been made to determine the aerodynamic characteristics in pitch and sideslip of a 1/15-scale model of the Scout vehicle at a Mach number of 2.01. The effects of two sets of cruciform fins, of inline and indexed fin arrangements, a flare, and accessories such as antennas, launch fittings, and control tunnels were measured for combined angles of attack and sideslip to about 8°. The tests were made in the Langley 4- by 4-ft supersonic pressure tunnel at a Reynolds number of 4×10^6 per foot.

Addition of the rear fins or the flare increased the longitudinal and directional stability, whereas the front fins, either indexed or inline, had a destabilizing effect. All configurations became directionally unstable with increasing angle of attack. The accessories had only a small effect on the aerodynamic characteristics other than an increase in axial force.

From author's summary

5706. Multhopp, H., Design of hypersonic aircraft, *Aero/Space Engng.* **20,** 2, 8–9, 32, 34, 36, Feb. 1961.

5707. Smith, C. C., Jr., Hovering and transition flight tests of a 1/5-scale model of a jet-powered vertical-attitude VTOL research airplane, NASA TN D-404, 30 pp., May 1961.

This vertical-attitude airplane, which is powered by a single turbojet engine, has a triangular wing mounted high on the fuselage with a triangular tail on top of the wing and has no horizontal tail. The airplane has conventional elevon and rudder controls for use in normal flight and has jet-reaction controls for use in hovering and at low airspeeds. The investigation included stability and control flight tests of the basic model configuration and also included a study of the effects of engine gyroscopic moments on stability and control. From author's summary

5708. Neal, B., Operating experience with a large scale mobile VTOL test rig, Nat. Res. Counc. Canada, Div. Mech. Engng. and Nat. Aero. Estab. Quart. Bull. 4, 55–67, Oct./Nov./Dec. 1960.

5709. Dingeldein, R. C., Consideration of methods of improving helicopter efficiency, NASA TN D-734, 17 pp., Apr. 1961.

Recent NASA helicopter research indicates that significant improvements in hovering efficiency, up to 7 per cent, are available from the use of a special airfoil section formed by combining an NACA 632A015 thickness distribution with an NACA 230 mean line. This airfoil should be considered for flying-crane-type helicopters. Application of standard leading-edge roughness causes a large drop in efficiency; however, the cambered rotor is shown to retain its superiority over a rotor having a symmetrical airfoil when both rotors have leading-edge roughness.

A simple analysis of available rotor static-thrust data indicates a greatly reduced effect of compressibility effects on the rotor profile-drag power than predicted from calculations.

Preliminary results of an experimental study of helicopter parasite drag indicate the practicability of achieving an equivalent flat-plate parasite-drag area of less than 4 square feet for a rotor-head–pylon–fuselage configuration (landing gear retracted) in the 2,000-pound minimum-flying-weight class. The large drag penalty of a conventional skid-type landing (3.6 square feet) can be reduced by two-thirds by careful design. Clean, fair, and smooth fuselages that tend to have narrow, deep cross sections are shown to have advantages from the standpoint of drag and download. A ferry range of the order of 1,500 miles is indicated to be practicable for the small helicopter considered.

From author's summary

5710. Maynard, J. D., Aerodynamic characteristics of parachutes at Mach numbers from 1.6 to 3, NASA TN D-752, 55 pp., May 1961.

A wind-tunnel investigation has been conducted to determine the parameters affecting the aerodynamic performance of drogue parachutes in the Mach number range from 1.6 to 3. Flow studies of both rigid- and flexible-parachute models were made by means of high-speed schlieren motion pictures and drag coefficients of the flexible-parachute models were measured at simulated altitudes from about 50,000 to 120,000 feet.

Porosity and Mach number were found to be the most important factors influencing the drag and stability of flexible porous parachutes. Such parachutes have a limited range of stable operation at supersonic speeds, except for those with very high porosities, but the drag coefficient decreases rapidly with increasing porosity.

From author's summary

5711. Cassidy, M. D., and Sullivan, P. J., Supersonic ejectable-nose escape capsule, *Aero/Space Engng.* **20,** 3, 14–15, 38–42, 44–45, 48, 50, Mar. 1961.

Astronautics

(See also Revs. 5180, 5190, 5191, 5192, 5193, 5215, 5221, 5358, 5477, 5503, 5509, 5608, 5647, 5660, 5671, 5775)

5712. Rauch, L. M., and Riddell, W. C., The iterative solutions of the analytical N-body problem, *J. Soc. Indust. Appl. Math.* **8,** 4, 568–581, Dec. 1960.

Authors discuss a solution of the N-body problem by functions regular in a region. The system of equations of motion is regularized by transformation employed by Sunderman. A corresponding iterative system of regularized differential equations is developed; the formal solution, a recursive formula, is reduced to a nonrecursive form. The initial functions are arbitrary. The computation of certain quantities in the iterations is based on Steffensen's technique for the regular solution of the 3-body problem. Finally, it is shown that the limit of the sequence of solutions is the actual solution of the system of differential equations.

G. R. Miczaika, USA

5713. Kozai, Y., The gravitational field of the earth derived from motions of three satellites, *Astronomical J.* **66,** 1, 8–10, Feb. 1961.

Orbital data from three satellites, 1958 β 2, 1959 η, and 1959 λ are used to determine the coefficients of the second, third, fourth and fifth harmonics of the earth's gravitational field. Results indicate that the fifth harmonic terms are significant. Values of the coefficients are compared with the values derived by O'Keefe et al in Smithsonian Astrophysics Observatory Special Report #51, 21, 1960.

R. K. Sherburne, USA

5714. Musen, P., Application of Hansen's theory to the motion of an artificial satellite in the gravitational field of the earth, *J. Geophys. Res.* **64,** 12, 2271–2279, Dec. 1959.

In order to draw geophysical and geodetic conclusions from the motion of the artificial satellite, we need an accurate theory that will permit the easy inclusion of any gravitational term. This article contains a theory of Hansen's type adaptable to the use of large computing machines. The form of the disturbing function suggests the use of the process of iteration. The computations can be carried out to any desired order compatible with the accuracy of the geodetic parameters. The theory as written is valid for zonal harmonics of all orders in the Earth's gravitational field. A program based on this theory was developed by Dr. Herget and his collaborators and was used by the Vanguard Computing Center to produce the numerical theories of several satellites.

From author's summary by A. Miele, USA

5715. Bailie, A., and Bryant, R., Osculating elements derived from the modified Hansen's theory for the motion of an artificial satellite, NASA TN D-568, 8 pp., Jan. 1961.

The modified Hansen's theory, which heretofore gave only the position vector of the satellite, is used for the derivation of the velocity vector and the osculating elements. Comparison with other general perturbation theories and with special perturbation techniques is now possible.

From authors' summary by A. Miele, USA

5716. Arthur, P. D., and Karrenberg, H. K., Atmospheric entry with small *L/D*, *J. Aerospace Sci.* **28,** 4, 351–352 (Readers' Forum), Apr. 1961.

The "Straight-Line-Trajectory" atmospheric-entry analysis of Allen and Eggers [NACA Report 1381, 1958] is extended to a small constant lift/drag ratio situation. The elevation angle above the local horizon is assumed small and negative during entry. Flat earth and constant g are also assumed. Maximum deceleration, heating, dynamic pressure, and Reynolds number are determined. As L approaches 0 the results approach those of Allen and Eggers.

R. K. Sherburne, USA

5717. Cobb, E. R., Optimum staging technique to maximize payload total energy, *ARS J.* **31,** 3, 342–344, Mar. 1961.

The Lagrangian multiplier method was used to derive a technique to minimize a missile gross takeoff weight with the payload total energy per unit weight as a constraint. The resulting equations are presented as a closed-form solution and are applicable to a general case where different mass ratios, specific impulses, attitude angles and initial thrust-to-weight ratios are inherent in missile stages. An example showing the comparison of the total energy constraint optimization technique with the velocity constraint optimization technique is included. From the results of this example, it appears that the energy constraint approach need only be considered for small missiles where the altitude is significant with respect to the velocity.

From author's summary by C. C. Wan, USA

5718. Rider, L., Characteristic velocity requirements for impulsive thrust transfers between non-co-planar circular orbits, *ARS J.* **31,** 3, 345–351, Mar. 1961.

An analysis is made of four types of two- or three-impulse transfers and the velocity requirements for each transfer type are compared to the characteristic velocity requirement of a "Mod-1 Hohmann"-type transfer where a non-coplanar velocity component is incorporated at the apogee of the transfer ellipse to rotate the orbital plane through the required relative inclination between the initial and the final circular orbits. In the "Mod-2 Hohmann" transfer, plane change is distributed between the two impulsive velocity increments. In the "Mod-1 bi-elliptic" transfer, the entire plane change is accomplished at the apogee of the transfer ellipse (second impulse). In the "Mod-2 bi-elliptic" transfer, plane change is distributed as in the case of the "Mod-2 Hohmann" transfer using two impulses, with each of the partial plane changes accomplished on the line of intersection of initial and final orbital planes and simultaneously with each of the coplanar velocity applications. In the "Mod-3 Hohmann" transfer, none of the three impulses are applied on the intersection of initial and final orbital planes; the first and the third velocity increments are applied at the transfer apsides with a plane change incorporated in each, while the second velocity increment will occur at some intermediate point of the ascent ellipse and will change only the direction but not the magnitude of the velocity at that point.

Comparison of velocity requirement economy is made in terms of the ratio of velocity savings to the velocity requirement of the "Mod-1 Hohmann" transfer for all points in the configuration space, defined by the ratio of inner to outer circular orbit radii and the relative angle of intersection between the orbital planes. Each of the four transfer types is found to provide significant economy (greater than 5 per cent) in certain regions of this configuration space. A summary chart is included in the conclusion of this paper.

C. C. Wan, USA

Book—5719. LeGalley, D. P., edited by, Re-entry and vehicle design, Vol. 4 (Proceedings of the Fifth Symposium on Ballistic Missile and Space Technology, Los Angeles, August, 1960), New York, Academic Press, 1960, x + 422 pp. $9. (Revs. 5719–5731)

5720. Friedman, H. L., The pyrolysis of plastics in a high vacuum arc image furnace, 3–29.

5721. Scala, S. M., and Nolan, E. J., Aerothermodynamic feasibility of graphite for hypersonic glide vehicles, 31–63.

5722. Swann, R. T., An engineering analysis of the weights of ablating systems for manned reentry vehicles, 65–86.

5723. Bendor, E., Krenkel, A. R., and Kottler, C., Trajectories of lifting bodies entering planetary atmospheres at shallow angles, 89–112.

5724. Dryer, M., Propulsive control of atmospheric entry lifting trajectories, 113–134.

5725. Arenz, R. J., and Williams, M. L., A photoelastic technique for ground shock investigation, 137–152.

5726. Marble, J. D., Rocket casing behavior predicted by laboratory tests, 153–172.

5727. Conte, S. D., Miller, K. L., and Sensenig, C. B., The numerical solution of axisymmetric problems in elasticity, 173–202.

5728. Woodis, W. R., Performance considerations for a VTOL boost vehicle using turbo-ramjet engines, 205–254.

5729. Meissner, C. J., Some considerations for the preliminary structural design of liquid fueled boosters, 255–281.

5730. Love, C. C., Jr., Liquid hydrogen storage parameters for a lunar voyage, 283–314.

5731. Draim, J. E., and Stalzer, C. E., Sea launch of large solid-propellant rocket vehicles, 339–375.

Ballistics, Explosions

5732. White, D. R., Turbulent structure of gaseous detonation, *Physics of Fluids* **4,** 4, 465–480, Apr. 1961.

Author has performed detailed measurements of detonation parameters in 2 H_2 + O_2 + 2 CO at initial pressures from 0.01 to 1.4 atm in a 8.25-cm square shock tube, and ascribes deviations from calculated Chapman-Jouguet (C-J) equilibrium conditions to observed turbulence of the reaction zone behind the detonation front. Detonation wave velocities and pressures were measured by ion gaps and fast quartz gauges, and density by means of spark interferometry. Spectral luminosity observed by photomultipliers in the reaction zone was related to product concentration [CO] [O] and used to define approach to chemical equilibrium. Results of numerous experiments show that in overdriven detonations (when a shock wave precedes the detonation, which then propagates into a moving, heated medium) the state of gas behind the detonation front is found to be close to calculated C-J equilibrium values. In contrast, behind self-sustaining detonations (those propagating into a stationary medium at room temperatures), pressures and densities are found to be lower than calculated values. The self-sustaining detonations invariably appear to have a turbulent structure.

Following this observation author develops the equations of propagation for a discontinuity front incorporating turbulence, thus generating a new family of solutions of the C-J equations, dependent on the turbulence intensity. These states have very slightly higher velocities, lower densities and pressures than classical C-J solutions, in agreement with author's findings. No quantitative measurements of turbulence are presented, but it is suggested that turbulence effects also offer alternative explanation of lower densities observed by Duff et al [AMR **12**(1959), Rev. 2673] using x-ray absorption; of lower pressures measured by Edwards et al [AMR **13**(1960), Rev. 4248] by the velocity-of-sound method, and the higher velocities reported by Peek and Thrap [*J. Chem. Phys.* **26,** p. 740, 1957]. Author carefully notes that two-dimensional effects (front curvature and boundary-layer growth) also furnish plausible explanations of these deviations, and suggests further investigations. R. A. Stern, USA

5733. Bauer, A., Cook, M. A., and Keyes, R. T., Detonation-generated plasmas, *Proc. Roy. Soc. Lond.* (*A*), **259,** 1299, 508–517, Jan. 1961.

Complementing previous studies [AMR **12**(1959), Rev. 4768] authors present very distinct high-speed frame photographs of explosions from condensed phases, to demonstrate emission of luminous ionized gas clouds from free surface of the explosive immediately after initiation. A variety of explosive samples were introduced into larger glass vessels and detonated by exterior charges through the bottom of the vessel. Pictures of the air space in the vessel above the explosive sample show a luminous zone traveling away from the free surface. The zone follows vessel contours of "flows" as a gas and has a rounded front symmetrical about a normal to the free surface. Shocks are observed in and following the luminous zone, but none preceding it. Relative density of the zone was estimated by its volume change, and relative conductivity by means of a probe. In Dithekite-13, for instance, conductivity was found to increase at 3 times the rate of the density, a value much like copper.

Former views held luminous zone to be due to shock-heating of the air; authors now conclude that evidence is rather indicative of a cloud of ionized gas emitted by the free surface. The condensed phase reaction originating in the bulk reaches the free surface, emerging into the low-density air environment as a metastable state which survives as a luminous plasma cloud. Abrupt decay of the plasma into normal products of detonation later causes recombination shocks and associated wave patterns visible in many instances. R. A. Stern, USA

5734. Aziz, A. K., Hurwitz, H., and Sternberg, H. M., Energy transfer to a rigid piston under detonation loading, *Physics of Fluids* **4,** 3, 380–384, Mar. 1961.

Incompressible metal plate is accelerated from rest by normal impact of Taylor detonation wave which started at free boundary of HE, whose products obey $E = Pv/(\gamma - 1)$. Lax method is used to compute plate-velocity-time relation with $\gamma = 2.5, 3$, and 3.5 and compared with known result when $\gamma = 3$, and reflected shock is approximated by a compression wave. Efficiency of transfer of HE energy into plate varies only by order of 1 per cent over γ range stated. J. Corner, England

5735. Campbell, A. W., Davis, W. C., and Travis, J. R., Shock initiation of detonation in liquid explosives, *Physics of Fluids* **4,** 4, 498–510, Apr. 1961.

Experimental studies of the initiation of liquid explosives by strong plane shocks (pressures 50 to 100 kbar) are described. These experiments demonstrate thermal explosion as a result of shock heating in the explosive. When the shock enters the explosive is heated. After a delay, detonation in the heated, compressed explosive begins at the interface, where the explosive has been hot longest. The detonation proceeds through the compressed explosive at a velocity greater than the steady-state velocity in uncompressed explosive, overtaking the initial shock and overdriving detonation in the unshocked explosive. Most of the work has been done on nitromethane, but molten TNT, molten DINA, Dithekite 13, and single crystals of PETN are shown to behave in the same way. Experiments showing the effects of bubbles and shock interactions in the explosive are presented.

From authors' summary

5736. Campbell, A. W., Davis, W. C., Ramsay, J. B., and Travis, J. R., Shock initiation of solid explosives, *Physics of Fluids* **4,** 4, 511–521, Apr. 1961.

Initiation phenomena in solid explosives produced by strong shock waves are described. Shock pressures in the explosive are between 20 and 200 kbar. It is demonstrated that in the usual case the shock wave travels not as an inert shock, but as a shock to which the explosive contributes energy, probably from reaction at voids and defects. This slightly reacting shock travels at increasing velocity for some distance, typically 1 cm in the experiments

described, and then in a travel of perhaps 0.01 cm becomes full detonation, moving at full velocity. The increase to full detonation velocity occurs without overshoot. Experiments demonstrating the variation of sensitivity to shock with density, grain size, and other properties are discussed. The explosives studied are cyclotol B, TNT, plastic-bonded HMX, and nitromethane-carborundum mixtures. From authors' summary

Acoustics

(See also Revs. 5588, 5754)

5737. Heckl, M., Investigations on orthotropic plates (in German), *Acustica* **10**, 2, 109–115, 1960.

On the basis of Huber's equations for thin orthotropic elastic plates the author calculates the flexural wave input impedance, mean particle velocity, and radiated sound power for point excitation. The sound attenuation for an infinite plate is also calculated. The expressions derived are checked by measurements with corrugated and slotted plates.

From author's summary by J. Miklowitz, USA

5738. Isakovich, M. A., Nonlinear effects involved in certain acoustical problems, *Soviet Phys.-Acoustics* **6**, 3, 321–325, Jan./Mar. 1961. (Translation of *Akust. Zh., USSR* **6**, 3, 321–325, July/Sept. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

Nonlinear effects (correction to square terms) are considered in the case of the Sturm-Liouville problem and in the case of wave propagation in a waveguide. It is shown that, as opposed to the case of propagation in an unbounded space, there are no secular terms present in the solutions, with the exception of degenerate instances. It is shown that the absence of secular terms is the result of dispersion. From author's summary

5739. Cheng, S.-I., On the aerodynamic noise of a turbulent jet, *J. Aerospace Sci.* **28**, 4, 321–331, Apr. 1961.

A new model is advanced for analyzing the broad-spectrum noise of a turbulent jet. The shear layer bounding the turbulent jet is assumed to play an important role in modifying the "quadrupole sound radiation" from the interior. To the sound-emitting, small-scale turbulent eddies (with frequencies much higher than those of large-scale eddies), the laminar shear layer has an irregular contour, as if large-scale turbulent motions were frozen. The linearized analysis is then applied to the laminar shear layer to relate the acoustic oscillations across it.

R. C. Binder, USA

5740. Howes, W. L., Similarity of near noise fields of subsonic jets, NASA TR R-94, 68 pp., 1961.

Similarity relations for frequency-pass-band, as well as overall, time-averaged pressure fluctuations outside a jet are derived and tested using experimental data. Similarity of the pressure fields was found for different jet velocities, Nozzle contour dissimilarity and differing jet temperatures were found to limit seriously the application of the similarity relations, especially near the jet nozzle.

R. C. Binder, USA

5741. Sherwood, J. W. C., Transient sound propagation in a layered liquid medium, *J. Acoust. Soc. Amer.* **32**, 12, 1673–1684, Dec. 1960.

Ray analysis is made of sound propagation in a multi-strata medium. Author extends work of Pekeris and Longman [*J. Acoust. Soc. Amer.* **30**, 323–328, 1958; AMR **12**(1959), Rev. 2720] to multiple layers with source and receiver in different layers, and also obtains results in form more suitable for machine computation.

I. Dyer, USA

5742. Naugol'nykh, K. A., and Rozenberg, L. D., Optimum operating conditions for a high-power concentrator, *Soviet Phys.-Acoustics* **6**, 3, 352–355, Jan./Mar. 1961. (Translation of *Akust. Zh., USSR* **6**, 3, 352–355, July/Sept. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

The authors discuss the operation of a spherical focusing system when the intensity of the focused sound is high, in which case nonlinear effects distorting the waveform become important. They determine the working conditions of a concentrator that correspond to maximum velocity amplitude of the wave at the focus of the system. From authors' summary

5743. Lebedeva, I. V., Investigation of the Moscow State University Acoustics-Department reverberation chamber, *Soviet Phys.-Acoustics* **6**, 3, 326–334, Jan./Mar. 1961. (Translation of *Akust. Zh., SSSR* **6**, 3, 326–334, July/Sept. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

5744. Arkhangel'skii, M. E., and Pinus, G. N., Investigation of the effect of ultrasonic oscillations on the diffusion of an electrolyte in a gelatin gel, *Soviet Phys.-Acoustics* **6**, 3, 276–281, Jan./Mar. 1961. (Translation of *Akust. Zh., USSR* **6**, 3, 278–283, July/Sept. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

Authors investigated the influence of ultrasound with an intensity of 0.3 w/cm² in a frequency range from 500 kc to 9 Mc on the process of diffusion of a colored electrolyte in a gelatin gel. The diffusion rate was measured from the motion of the front of the dyed electrolyte as observed by means of a microscope. It is shown that a variable acoustic pressure acts directly to accelerate the diffusion process. From authors' summary

5745. Sirotyuk, M. G., Balance of energy in a concentrator designed to supply ultrasound of high intensity, *Soviet Phys.-Acoustics* **6**, 3, 409–411, Jan./Mar. 1961. (Translation of *Akust. Zh., USSR* 6, 3, 410–411, July/Sept. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

5746. Mikhailov, I. G., and Shutilov, V. A., Distortion of the finite-amplitude ultrasonic waveform in various liquids, *Soviet Phys.-Acoustics* **6**, 3, 340–346, Jan./Mar. 1961. (Translation of *Akust. Zh., USSR* **6**, 3, 340–346, July/Sept. 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

An optical method is used to determine the distortion of ultrasonic waveforms in order to measure the nonlinear parameters of liquids. The paper presents working equations for calculating the rate of deformation of the profile of a finite-amplitude wave during its propagation and the ratio of the coefficients in the nonlinear equation of state for the liquids. The results of measurements of these quantities in various liquids are given.

From authors' summary

Micromeritics

(See also Rev. 5616)

5747. Gast, T., Dust measuring devices for indication or recording on basis of proportional quantity (in German), *Staub* **20**, 8, 266–272, Aug. 1960.

Author discusses concept and definition of dust concentration, and its range of values occurring in mining practice. He discusses principle of gravimetric recording; describes the design and operation of a sensitive electronic balance, and its capabilities and limitations. The electrostatic charging device for precipitating the dust sample is described, and the methods and devices for ensuring constant air throughput, and for automatic programming

and operation, are illustrated and explained. The balance is made (by Sartorious-Werke, Goettingen, Germany) in three types, in order to accommodate the wide range of dust concentrations and environmental conditions; these differ in design, sensitivity, and programming of the measurement. Main headings: electronic weighing in the milligram range; dust balance for use in mines and dusty industries; application to investigation of industrial exhaust gas emissions; measurement of dust concentration in the atmosphere. The devices and their component parts are illustrated with schematics, circuit diagrams, and pictures.

This is an up-to-date orientation on the methods, and on some available devices, for industrial dust measurement on the problems encountered, as these are considered and solved in the German industry.

K. J. DeJuhasz, USA

5748. Robinson, A. R., Vortex tube sand trap, *Proc. Amer. Soc. Civ. Engrs.* **86,** IR 4 (*J. Irrig. Drain. Div.*), 1–34, Dec. 1960.

The vortex tube sand trap consists of a tube with an opening along the top and placed in the bed at an angle to the direction of flow, usually 45°. As flow passes over the opening a spiral motion is set up in the tube and material traveling along the bed is drawn or drops into the tube and is carried to an outlet at one end of the tube where it can be discharged. To prevent the opening of the tube becoming blocked by sand ripples it is necessary to operate it at Froude numbers large enough for ripples to be absent (0.8) and this usually involves installing the trap in a hump in the bed.

Numerous tests have been made to derive the design criterion for successful operation of the device.

G. H. Lean, England

5749. Breuer, H., Dust measurement in coal mining (in German), *Staub* **20,** 8, 290–299, Aug. 1960.

This is a detailed discussion of the hygienic, scientific, industrial, and organizational aspects of dust measurement in coal mining, as they exist in the German Federal Republic. Methods of dust sampling, by the tyndalloscope, mining conimeter, and fine-dust filter, are discussed, and the problems of directing the sampling to the harmful constituents of the dust, in the range below 5 micron, are considered. Differences in the pathological action of various dust materials, silicon, lime, coal, are pointed out. Evaluation of dust samples for particle-size distribution, for material components, silicon component, is shown in diagrams, and their interpretation from the point of view of health hazard for silicosis is explained. Organizational measures for mitigating the exposure of workers with incipient silicosis to aggravating conditions are indicated.

From the point of view of applied mechanics, the description of the various instruments, their principles and capabilities, and adaptation for the range of conditions existing in coal mines, are of special interest. The instruments described are: the tyndalloscope, fine-dust-measuring apparatus, conimeter, photoelectric dust-measuring apparatus; a testing tunnel for calibrating and evaluating the dust-measuring instruments is also shown and explained.

This extensive and authoritative paper gives a well-rounded orientation of the problems of industrial dusts in coal mining, and the scientific and technological methods for their appraisal and mitigation.

K. J. DeJuhasz, USA

5750. Rumpf, H., Investigations on the accuracy of grain size analysis (in German), *Staub* **20,** 8, 253–266, Aug. 1960.

Grain-size analysis describes a population of particles according to some definite characteristic, e.g., diameter, volume, mass, sinking velocity, by determining the percentage having the same value of the chosen characteristic. The characteristic is not always unambiguously definable but is subject to variation; this leads to an inaccuracy in the analysis. In Part I the various characteristics are discussed, defined, and their significance for behavior, processes and use indicated. These are: shape and size of grain, composition and density, sinking (terminal) velocity, and surface. Pertinent literature relative to these characteristics is surveyed.

In Part II a detailed survey is presented on the methods of measurement: sieving, sedimentation (by gravimetry, by diver, by pressure, by areometry, by photometry), elutriation, centrifugal separation, counting. For each method the fundamental mathematical and physical analysis is given, and pertinent literature is listed. In Part III the quantitative error analysis is presented for the sampling, the method of measurement, and the statistical representation.

This extensive paper represents a detailed coverage of the subject; the treatment is clear, logical, and authoritative. It is based on a systematic evaluation of recent work in this field, 29 items of which are listed, with authors' names and titles, for the period of 1940 to 1960. The last part, dealing with error analysis, is largely the original contribution of the author and K. Leschonski, developed in the Institut for Mechanical Processes at the Technische Hochschule Karlsruhe, Germany, of which the author is director.

K. J. DeJuhasz, USA

5751. Hage, K. D., Diehl, C. H. H., and Dudley, M. G., On horizontal flat-plate sampling of solid particles in the atmosphere, *AMA Arch. Industr. Health* **21,** 2, 124–131, 1960.

In the study of turbulent distribution of particles emitted from sources located at a height it is important to know the ratio of the total emitted amount and the amount accounted for by the collection network. Generally, both horizontal and vertical collecting surfaces are required; for larger particles horizontal collecting surfaces located near the ground are sufficient. In the present experiments small glass globules (about 108 micron diameter, dyed with fluorescent paint, were emitted from a point source from a height of 15 meter. The particles were collected on nine collectors (metal foils covered with acetate paper), located within 18 and 800 meter distance from the source. Influence of wind intensity and direction was found to be important.

K. J. DeJuhasz, USA

5752. Gillespie, T., Electric charge effects in aerosol particle collision phenomena, *International J. Air Pollution* **3,** 1/3, 44–49, 1960.

Author discusses first the distribution of electric charge on aerosol particles. He describes an apparatus in which the particles are passed through two vertically placed electrodes where they precipitate; their charge is determined from the position of the particles, their size, and the air velocity in the instrument; the uncharged particles are collected in a thermal precipitator. The apparatus is suitable for determining the variation of charge distribution of an aerosol as a function of time.

Electric charge on aerosol particles increases the rate of coagulation; experiments indicate that the coefficient of the rate of coagulation increases with increasing mean particle charge, as was shown experimentally on a glass-powder aerosol. The effectiveness of fibrous filters is increased if the particles are charged, especially if the fibers are also charged. It was found that precipitation of aerosols with large (about 1-mm diam) falling water drops is not influenced by electric charging.

K. J. DeJuhasz, USA

5753. Lassen, L., A simple generator for producing monodisperse aerosols in the size range of 0.15 to 0.70 micron particle radius (in German), *Z. Angew. Phys.* **12,** 4, 157–159, 1960.

Author describes an aerosol generator in which a polydisperse aerosol produced by cold atomization, which contains particles no

larger than a few micron, is subsequently evaporated in a heating zone to such an extent that no Tyndall effect appears. After leaving the heating zone the vapor condenses, without any addition of condensation nuclei, in a 1-meter long funnel, to a monodisperse aerosol. Author discusses the "residual-nucleus" hypothesis as an explanation of the formation of a monodisperse aerosol from a polydisperse aerosol; according to this the evaporation does not progress up to molecular dimensions, but from a portion of the primary fog particles some residual nuclei remain. This hypothesis is supported by some observational evidence. Developments are in progress to produce monodisperse aerosols of specified size, by varying the size distribution of the primary fog, using a commerical pneumatic atomizer and by varying the air pressure. By this method dioctylphthalate fog of 0.15 to 0.70 micron radius was obtained. Droplet size was measured by the "owl" device; variation of particle size is given as 10% of mean value. The generator produces about 10 to 20 liter aerosol per minute, with a concentration of about 10^6 to 10^7 particles per cu cm. K. J. DeJuhasz, USA

5754. Duchin, F. F., Theory of motion of an aerosol particle in a stationary sound wave (in Russian), *Kolloid. Zh., USSR* **22,** 1, 128–130, 1960.

Aerosol particles assume different concentrations in the nodes and in the anti-nodes of a standing sonic-wave field; this behavior results in a periodic particle distribution, which plays an important part in acoustic coagulation. Author develops new points of view regarding the mechanism of motion: it is assumed that the particles are acted upon by a quasi-periodic force which sets the particles into vibration whereby they are displaced during the period of vibration. The mean value of this force is by several powers of 10 higher than the sound pressure calculated from King's equation. The particles wander to and concentrate in the plane of the nodes; for particles greater than 0.1 micron the thermophoresis is not intense enough to counteract the wandering to the nodes. K. J. DeJuhasz, USA

5755. Cizinsky, V., and Kolousek, J., Ultra-centrifuge as aerosol generator and its practical and scientific application (in Russian), *Kolloid. Zh., USSR* **21,** 6, 739–746, 1959.

This ultra-centrifuge comprises a funnel-shaped stator with entry nozzles for the driving air, and a conical rotor with channels against which the entering air impinges; high-pressure air is supplied through a hose. With 10-atm supply air, about 200,000 rpm is attained; for inhalation purposes about 75,000 rpm is used. The atomizing disk has about 1-inch diameter; to it is fed the medicine to be atomized, at a rate of about 2 cu cm per min. The coarse drops are sedimented out; the fine droplets enter the room air; droplet size is regulated by altering the disk speed. Authors describe a bactericidal test using penicillin.

K. J. DeJuhasz, USA

5756. Nagy, I. V., and Karadi, G., Results of recent investigations into bed-load movement (in Hungarian), *Hidrológiai Közlöny* **40,** 3, 177–184, June 1960.

Authors conducted experiments from which they derived empirical values of current velocities capable of initiating sediment motion under different regimes of sediment transport. For details of the experiment reference is made to an earlier paper [Kalmar, unpublished manuscript, 1952]. The significance of particle size in relation to thickness of the laminar boundary layer is stressed. For hydraulically small particles (completely covered by the l.b.l.) and large particles (no l.b.l. exists) results similar to those of other authors, e.g. Liu, AMR **11**(1958), Rev. 512, and Bogardi, were obtained. However, by considering hydraulically medium-size particles (with a partially broken l.b.l.) authors obtained relationships different from those derived by earlier authors who failed to investigate this third size category. Results of the experiments are presented graphically.

G. Thuronyi, USA

5757. Eisenklam, P., Atomisation of liquid fuel for combustion, *J. Inst. Fuel* **34,** 243, 130–143, Apr. 1961.

The Imperial College of Science and Technology, High Speed Fluid Kinetics Laboratory, has been engaged for several years past in the study of liquid fuel atomization. The present paper summarizes the results of this work as it pertains to spray combustion; it also points out gaps in existing knowledge on the mechanism of combustion, component elements of which are: reaction chemistry, mass transfer (evaporation), fluid flow or mixing. Atomization is one way of preparing a liquid fuel for evaporation. The atomizer disintegrates the liquid, and projects and disperses it in the preferred direction. The drops produced in the vicinity of the atomizer form the "initial spray" and they diminish in size during their flight; drops within the combustion chamber at any instant form the "resident spray" whose mean drop size and size dispersion are different from those of the initial spray. First chapter, on mass transfer from sprays, treats rate of vaporization, interfacial area, concentration gradient, and mass-transfer coefficient; for all those subjects clear mathematical expositions are given; previous research work is reviewed in considerable detail. A chapter on formation of drops discusses instability of liquid sheets and drops, shatter of drops and their coalescence, with typical photos, and includes surveys of previous work.

Another chapter, on atomizing devices, describes the characteristics of pressure atomizers, rotary atomizers, and twin-fluid atomizers. The following chapter, on the performance of atomizers, deals with flow rate, spatial configuration of the spray, drop size, determination of drop size and drop-size distribution, and performance of sprays obtained from atomizers of various types. A rather extensive bibliography is given of the more important papers published during the past ten years or so, including some still earlier publications, which is a useful guide for those desiring more detailed information on some of the topics discussed. But even without such collateral reading, the present extensive paper should give a clear and up-to-date orientation on the present status of the subject, and a good introduction for further study. K. J. DeJuhasz, USA

Porous Media

(See also Revs. 5433, 5586, 5624, 5756)

Book—5758. Pore pressure and suction in soils (Conference sponsored by British National Society of International Society of Soil Mechanics and Foundation Engineering at Institution of Civil Engineers, 30–31, Mar. 1960), London, Butterworths, 1961, 151 pp. $11.25.

Skempton shows that Terzaghi's expression of effective stress equals total stress minus pore-water pressure is satisfactory for saturated soils but not for very dense materials, which require different adjustments for shear and volume change. For unsaturated soil an additional adjustment is required for the effective area of air and water pressure. Jennings and Aitchison evaluate these adjustments by tests. Change in potential is used by Schofield to express pore pressure in swollen clay. Gardner uses gravity, osmotic and capillary potential to calculate rates of infiltration, evaporation and transpiration. Croney and Coleman review applications and measurement of suction, defined as negative pore pressure with no external load. Discussions relate different viewpoints and aim to simplify nomenclature.

French work in theory, laboratory and field is reviewed by Peltier, while Habib describes three pressure-measuring devices. Nash and Dixon record pore pressures in sand compressed 8000% per minute. Rate of stress distribution is stressed by Bishop's negative pore pressure measurements in triaxial tests and Penman's field piezometer tests. Little and Vail describe hydraulic piezometers using nylon tubing and various deairing devices. Field pressure measurements are compared with stability theory—during drawdown by Paton and Semple, between vertical sand drains and horizontal blankets by Bishop, Kennard and Penman, and near piles driven in a bank by Bjerrum and Johannessen. Measured pressures are related to consolidation—in London clay by Skempton and Henkel; under a cyclicly loaded oil tank by Gibson and Marsland; and in peat by Lake.

E. S. Barber, USA

5759. Baker, W. J., The flow of oil and gas mixtures in wells and pipelines: Some useful correlations, *J. Inst. Petroleum* **47,** 449, 162–169, May 1961.

Calculations relating to the flow of oil and gas mixtures in oil wells and pipelines involve the integrals of (vdp) and (ρdp). General correlations have been obtained from 22 Middle East crudes which enable these integrals to be evaluated for any pressure changes occurring in a well or pipeline. It is estimated that the correlations are about 5 to 10 per cent accurate for oils with stock tank specific gravities in the range 0.80 to 0.92 (45° to 22° API). A correlation of gas-oil ratio with saturation pressure, similar to that of Standing, has also been obtained.

These correlations simplify the design of oil-well flow-strings and flowlines to the extent that it becomes no more difficult than designing for single phase flow. At the same time it is only necessary to know the saturation pressure and stock tank gravity of the oil in order to carry out flow calculations within reasonable limits of accuracy.

The method of plotting the integrals, in which pressures are expressed as fractions of the saturation pressure, results in a single curve covering the whole range in saturation pressures. This is of particular value in that it means that it is only necessary to establish the relationship at one saturation pressure. The use of the curves can thus be extended to include the case of a well producing at higher than the original gas-oil ratio, or by gas lift, by using an equivalent saturation pressure obtained from the correlation of gas-oil ratio and saturation pressure. A condition that must be satisfied in using the correlations is that the oil and gas flow is an intimate mixture and no separation of the two phases occurs.

From author's summary

5760. Mortada, M. Oilfield interference in aquifers of nonuniform properties, *J. Petroleum Technol.* **12,** 12, 55–57 (Tech. Note), Dec. 1960.

An analytical approach to oilfield interference in idealized though not necessarily common situations. It is concluded that in studying oilfield interference the variations in properties of the aquifer must be taken into account to obtain reliable results. Simplifications permitted in dealing with oilwell interference cannot be applied to oilfield behavior.

J. C. Geyer, USA

5761. Carter, R. D., and Tracy, G. W., An improved method for calculating water influx, *J. Petroleum Technol.* **12,** 12, 58–60 (Tech. Note), Dec. 1960.

A method based on an approach by Hurst is developed for calculating water influx behavior. Using this method, superposition calculations may be eliminated. The principal difference between this method and that of Hurst is that, over finite intervals of time, constant oil-production rates are assumed by Hurst whereas constant water-influx rates are assumed in the presently described method.

Use of this method of calculating water-influx behavior should result in a considerable saving of time as compared to superposition calculations when the calculations must be made without using a digital computer.

From authors' summary by J. C. Geyer, USA

5762. Murray, J. A., Relaxation methods applied to seepage flow problems in earth dams and drainage wells, *J. Instn. Engrs., India* **41,** 4 (Part 1), 149–161, Dec. 1960.

A brief summary of seepage problems solved by use of relaxation methods is presented. The survey is far from complete but may serve some useful purpose in reiterating the general usefulness of relaxation procedures.

O. C. Zienkiewicz, USA

5763. Yih, C.-S., Exact solutions for steady two-dimensional flow of a stratified fluid, *J. Fluid Mech.* **9,** 2, 161–174, Oct. 1960.

Author studies the two-dimensional flow of an inviscid stratified incompressible fluid. The main principle of the method consists in replacing the velocity components u and w by the pseudo-velocity components

$$u' = u(\rho/\rho_0)^{1/2} \qquad w' = w(\rho/\rho_0)^{1/2},$$

ρ being the density.

Author is thus able to define a pseudo-stream-function ψ' and to determine the stratifications laws so that the equations become linear. Three distinct classes of flows are shown, for which the problem is linear, and for each of said classes, exact solutions of the corresponding equations are researched. Two of the three classes of solutions have close bearings on the lee-wave problem in meteorology. Some of the results given in this paper, as stated by author, had already been obtained with a different method by R. R. Long [*Quart. J. Roy. Meteor. Soc.* **84,** 1958].

C. Ferrari, Italy

5764. Gheorghitza, St. I., Motions with initial gradient, *Quart. J. Mech. Appl. Math.* **12,** 3, 280–286, Aug. 1959.

This paper is concerned with the motion of incompressible fluids in a porous medium taking place only when the modulus of the gradient of the dynamic pressure surpasses a given value. The Eq. [12], which is satisfied by the function ϕ defined by [1] and [3], is deduced.

A general approximate method of solution is described, and some particular exact solutions are obtained.

From author's summary

5765. Donetskii, V. N., A precise and an approximate calculation for the inflow into a battery of oil wells disposed in a circle (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Neft'igaz.* no. 1, 35–40, 1959; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13768.

The case is investigated in precise conditions of the interference of batteries consisting of m wells of equal yield, located at the top of a regular m-square in a round stratum, bounded by areas with radii R_1 and R_2 when $R_1 < R_2$. Corresponding filtration potentials Φ_1 and Φ_2 are assigned to these areas. On the contours bounding the wells the potential is equal to Φ_c with a radius for the well of r_c. The problem is to determine the yield. The method of conforming conversions is used to solve the problem. The paper continues by offering an approximate solution for the same problem by using the method of filtration resistances. A comparison of the solutions obtained shows that the mean relative error resulting from the determination of the yield by the method of filtration resistances does not exceed 1%.

M. V. Filinov

Courtesy Referativnyi Zhurnal, USSR

5766. Gutman, E. M., Investigation of filtrational transfer in capillary porous systems (in Russian), *Inzhener.-Fiz. Zh.* **1,** 10, 62–68, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13775.

A certain parameter P is put forward in the first part of the article to characterize the degree of dispersion of the particles, constituents of the porous medium and their form. This parameter is determined as the mean magnitude of the relation of the perimeter to the area of all possible sections of the particle proportional to the specific surface of the particle. The measuring of this parameter is proposed to be effected by means of the number of intersections of the network of parallel straight lines on the plane of the section (polished micro-section) of the soil with the boundaries of the particles, using the solution of Buffon's known problem in the theory of probability for the purpose. A method is suggested for ascertaining the porosity and the mean radius of the pores in accordance with the data for the given structure. In the second part of the article the parameter P is used for improving Cozeni's formula for finding the coefficient of porosity and the formulas for the Knudsen flow of a rarefied gas through a porous grid; these formulas had been previously derived on the basis of the theory of the hydraulic radius.

V. N. Nikolaevskii

Courtesy Referativnyi Zhurnal, USSR

5767. Kaplinskoi, M. I., Determination of the coefficient of filtration and the magnitude of filtrational losses when taking into account the capillary zone and the incomplete saturation of the pores with water (in Russian), *Trudi Yubilein. Nauchn. Sessii Akad. Nauk KirgSSR, Otd. Estestv. i Tekhn. Nauk, Frunze,* 1958, 309–329; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13778.

An approximate deduction is put forward for the known formula for the permeability of the soil when its pores are incompletely filled with the liquid being filtered off. Various empirical relations are adopted for the humidity in the capillary zone to the height; determinations are made for the mean suspension values of porosity to the height; and calculations are made for the brought-in height of capillary rise as laid down by S. F. Aver'yanov [*Doklady Akad. Nauk SSSR* **69**, no. 3, 1949]. The paper continues by giving the results of calculations of the free filtration from canals made in accordance with known methods but taking into account the brought-in height of capillary rise. These results are compared with the data of experiments carried out by the author. The author came to the same conclusion as did other authors, namely, that when making calculations for filtrational losses account should be taken not of the full height of the capillary rise but of only a portion of it, ordinarily known as the height of the capillary vacuum.

N. N. Verigin

Courtesy Referativnyi Zhurnal, USSR

5768. Levitskii, B. F., The displacement of petroleum by water in a horizontal stratum when the contour of the petroleum-bearing layer is not parallel with the gallery (in Russian), *Dop. Akad. Nauk URSR* no. 6, 617–619, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13786.

Paper deals with certain modifications of V. N. Shchelkachev's formula, regarding the determination of the locus of the water-petroleum contact in the stratum, obtained by him on the basis of the method of isolated tubes. The case is investigated of the out-of-parallel gallery of the initial position of the contour of the petroleum-bearing layer. Actually the modifications center on the subtraction from the fluid of the coordinates of the particle, moving in one of the tubes, of its initial coordinates. The author's reasoning on the presentation of the mass forces of resistance of the porous medium as being in the form of surface forces of friction is not correct [see *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 9, 145–147, 1957].

V. N. Nikolaevskii

Courtesy Referativnyi Zhurnal, USSR

5769. Sergeevich, V. I., and Zhuze, T. P., The viscosity and density of typical waters found in oil fields in conditions prevailing in the strata (in Russian), *Neft. Kh-vo* no. 12, 57–61, 1958; *Ref. Zh. Mekh.* no. 11, 1959, Rev. 13799.

Investigations carried out in the Institute for petroleum of the Academy of Sciences USSR are described showing the influence of pressure, temperature and degree of gas saturation on the viscosity and density of water types in petroleum sites. A plan is given of the apparatus used for the determination of the viscosity and density of the water both when saturated with gas and free from gas. Descriptions are furnished of methods for the determination of viscosity and density on special devices, part of the experimental apparatus and also of a method for determining the quantity of gas dissolved in the waters. The values of the viscosities of the waters investigated at different temperatures (from 5 to 140°) and pressures (up to 500 atm) corresponding to the strata conditions are furnished. The relation of the viscosities of calcium chloride-containing, brine-containing (sea) and pure water to the temperature, for a number of constant pressures is presented in the form of graphs. The magnitudes of the viscosity and density of some typical stratum waters saturated with methane in a pressure range of from 50 to 300 at a temperature of 40° are given in tabular form. Calculations are made in accordance with the density data for the mean coefficients of compressibility for waters of the following types: sodium hydrocarbonate, magnesium chloride, sodium sulphate and calcium chloride. The main conclusions drawn from the investigations carried out comprise: (1) The characteristic magnitude for different types of strata waters is the density, the highest-ranking being waters of the calcium-chloride type. (2) The influence of pressure on the viscosity depends on the temperature, the nature and concentration of the dissolved salts. (3) A rectilinear relation is established between the density and pressure at all temperatures. The presence of methane in the waters reduces the density to a small extent.

I. G. Bulina

Courtesy Referativnyi Zhurnal, USSR

5770. Coupe, R. R., and Hsu, B., Effects of viscosity, pressure and time on the penetration of varnishes and inks into paper, *Appl. Scient. Res.* (*A*) **10**, 3/4, 253–264, 1961.

The penetration of varnishes and inks into supercalendered paper under pressure was studied by means of reflectance measurements. The penetration appeared to be proportional to the square root of the ratio of the magnitude and duration of the applied pressure to the viscosity. This relationship is in agreement with the classical physical law for the viscous flow of fluid into a porous medium. It is also concluded that for the systems studied the ink penetrates, under the applied pressure, as a homogeneous body into the paper with no filtration of pigments from the carrying varnish.

From authors' summary

Geophysics, Hydrology, Oceanography, Meteorology

(See also Revs. 5232, 5402, 5586, 5741)

5771. Egyed, L., and Stegena, L., On the physical foundation of the earth's expansion (in Hungarian), *Geofiz. Kozlemenyek* **9**, 1/2, 23–30, 1960.

Author's earlier investigations led to the conclusion that the Earth is continuously expanding. In this paper he gives a physical interpretation of this expansion. The Earth's mantle, outer core and inner core are assumed to consist of three different states of the same composition, and a constant transformation is believed to take place of the inner into the outer core and of the outer core into the mantle. According to Ramsey's theory (1949) such a transformation can occur if the pressure in the Earth's interior constantly decreases, which is possible only if the gravity coef-

ficient decreases with time. Gilbert (1956) proved that this latter assumption can be deduced from the general theory of relativity. On the basis of these theories, and using Bullen's data on the Earth's density, the author computes the annual increase of the Earth's radius and finds it to be at least 0.3 mm. This corresponds to the lower limit of author's earlier findings which were based on geophysical measurements. G. Thuronyi, USA

5772. Voit, S. S., On the propagation of tidal waves on the surface of a rotating liquid in the presence of boundaries, *Soviet Phys.-Doklady* **4,** 4, 765–768, Feb. 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **127,** 4, 764–767, July/Aug. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

5773. Munn, R. E., A theoretical expression for the root mean square vertical eddy fluctuation $(\overline{w'^2})^{1/2}$, *J. Meteorol.* **18,** 1, 38–42, Feb. 1961.

A theoretical expression is derived for the root-mean-square vertical-eddy fluctuation $(\overline{w'^2})^{1/2}$ in terms of the friction velocity, the height and Monin and Obukhov's function ϕ. Steady-state conditions and constant shearing stress are assumed. It is shown that $(\overline{w'^2})^{1/2}$ increases with height under superadiabatic conditions, is constant with height when the lapse rate is adiabatic, and decreases with height during inversions. Indirect evidence suggests that the height variation of $(\overline{w'^2})^{1/2}$ can be approximated by a power law. From author's summary by G. E. Jarlan, Canada

5774. Bryan, K., The instability of a two-layered system enclosed between horizontal, coaxially rotating plates, *J. Meteorol.* **17,** 4, 446–455, Aug. 1960.

The motion of two homogeneous layers of fluid enclosed between horizontal plates, which rotate coaxially at slightly different angular velocities, has been investigated. The solution for the zonally symmetric forced motion is only a slight modification of a solution of Stewartson's (1953) for a single fluid between rotating disks. Experiments with the two-layer system confirmed the existence of symmetric motion, but for a certain range of parameters it was unstable. A criterion for instability of the symmetric flow was developed from appropriate inviscid, quasi-geostrophic frequency equations, using an approximate variational method. A comparison with experiment indicated stability for somewhat greater shear across the interface of the two layers than predicted.

Exploratory experiments in the unstable range demonstrated that the number of disturbances tended to increase directly as the rotation rate and inversely with the density difference. A steady wave pattern was observed only when the horizontal dimensions of the disturbance were comparable to the diameter of the cylindrical container. The shape of the steady disturbance was such as to give a strong transport of momentum inward.

Certain analogies are drawn between eddy circulation observed in the experiments and low-level cyclones in the atmosphere and meanders of upper-level ocean currents.

From author's summary by G. E. Jarlan, Canada

5775. Blagonravov, A. A., and Kroshkin, M. G., Geophysical research with the aid of rockets and artificial satellites, NASA TT F-57, 17 pp., Feb. 1961.

Naval Architecture and Marine Engineering

(See also Revs. 5425, 5510, 5522, 5525, 5539)

Book—5776. Djodjo, B. A., Ship analyzers—Analog computers for efficient ship calculation (Monograph Vol. 337, no. 7, Institute of Mechanical Engineering, Vladimir Farmakovski), Beograd, Serbian Academy of Sciences and Arts, 1960, ix + 119 pp. (Paperbound)

Monograph discusses application of analog devices to calculation of ship hydrostatic curves. Discussion uses mechanical analogy to demonstrate principles. Included are brief discussions of theory, electrical and optical methods of analog computation. Author has included a brief discussion on the BUSAC (Bureau of Ships Analog Computer). Discussion is general and does not include worked examples.

This reviewer's opinion is that the monograph is like a discussion written fifty years ago. In spite of the author's contention, the methods he discusses have been made obsolete by the digital computer. This is especially true since many small lower cost machines are now available. The discussion has suffered in translation since the English is awkward.

G. L. West, Jr., USA

5777. Kolberg, F., Investigation of the wave resistance of ships in shallow water in the case of uniform shearing flow (in German), *ZAMM* **39,** 7/8, 253–279, July/Aug. 1959.

For the computations of the wave resistance of ships, the relative flows around the ships are usually assumed to be potential flows. The present theoretical study of the alterations of the wave pattern far behind the ship and of the wave resistance in the considered case is based on some other approximations. The basic differential equations and the boundary conditions are linearized. The cases of undercritical and overcritical velocities corresponding to water surface are considered separately.

In the first case the main factor is the maximum longitudinal wavelength and in the second case it is the angular aperture of the wave field. Heights of the wave are different for ship going downstream and going upstream. Computations and results of model experiments will be published later.

R. Spronck, Belgium

5778. Dubov, V. P., Investigation on a model of the seiches (apparent tides in a lake) in the Aralsk sea (in Russian), *Nauchn. Zap. Mosk. In-ta Inzh. Vodn. Kh-va* **20,** 321–329, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 11748.

Results are described of the calculations for the seiches of the one-, two- and three-nodal forms in the Aralsk sea on the basis of experiments carried out on models.

For the recalculation of the data given by the model for full scale Solov'ev's formula was utilized:

$$T = T' \frac{m}{\sqrt{n}} \left[1 + \frac{1}{6}\left(\frac{2\pi b}{\lambda}\right)^2\right]^{-1} \frac{2\pi}{2\pi + \delta} \qquad [1]$$

where T' represents the seiche periods on the model, $1/m$ and $1/n$ are the horizontal and vertical scales of the models, b is the mean depth of the model, λ is the length of the wave, δ is the logarithmic decrement of the damping of the wave. Charts are given and plans for the distribution of the nodes and the protuberances of the seiches. Discussion of the conditions of modeling according to Froude and substantiation for formulas [1] are not given in the paper. N. N. Moiseev

Courtesy Referativnyi Zhurnal, USSR

5779. Sysoev, N. N., An electromagnetic method of measuring the flow when the ship is in motion (in Russian), *Okeanogr. Komis. Akad. Nauk SSR* **3,** 138–146, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 11772.

A method is described for measuring the surface flows when the ship is in motion, based on the determination of the *emf* induced in the conductor moving in a magnetic field. Some information is furnished on the apparatus utilized and some ideas expressed

regarding the evaluation of the precision of the electromagnetic method for measuring the flows. S. S. Voit

Courtesy Referativnyi Zhurnal, USSR

5780. Fedyaevskii, K. K., and Shebalov, A. N., An approximate evaluation of the influence of shoal water on the shoulder of the heeling hydrodynamic moment when the ship is moving with a list (in Russian), *Trudi Leningr. Korablestroit. In-ta* no. 22, 3–9, 1958; *Ref. Zh. Mekh.* no. 10, 1959, Rev. 11779.

The absence of an exact method for calculating the point of application of hydrodynamic forces of pressure when the ship is moving with a list is referred to. An approximate qualitative evaluation is given on the influence of shoal water on the shoulder of the heeling hydrodynamic moment. Use was made of the experimental investigation on the breaking away of the turbulent boundary layer in elliptical cylinders, work which was done in the hydrodynamic laboratory of the Moscow State University, and the solution of the problem on the transverse flow about of a grid of ellipses. The calculations made indicate that the influence of shoal water on the shoulders of the heeling hydrodynamic moment when the ship is moving with a list is considerable; consequently this should be taken into account when investigating the transverse motion of a ship in shoal water.

V. B. Dragomiretskii

Courtesy Referativnyi Zhurnal, USSR

5781. Borg, S. F., The analysis of ship structures subjected to slamming loads, *J. Ship Res.* **4,** 3, 11–27, Dec. 1960.

Paper describes an interesting fundamental study of various phases of response of a simplified ship structure to slamming-type loads. Great stress is placed upon phenomenological considerations. It is distinguished between three time regions: period of localized effect, of transition, and of over-all effect. It is assumed that velocity of travel of stress or displacement effects is 10,000 fps as an average. Calculations are based on energy considerations. Different damping losses are discussed; internal friction in steel only (and rivet-slip in riveted ships) is concluded to be important. Scaling factors involved in vibrational damping are also discussed and it is shown possible to simultaneously satisfy all dynamic scaling parameters developed.

Author proposes an approximate analysis of ship hulls subjected to slam loads. In first place stresses are assumed to be within elastic range. Analysis is concemed with responses in only two of above time regions, namely period of transition and of over-all effect. For period of transition method of solution is based upon wave-transmission characteristics of ship hull; a shear-bending wave travels down the length of ship and introduces balancing inertia forces and shear deflection only as bending deflection has no time to develop. This is equivalent to the "shudder" of ship. For period of over-all effect, method of solution is based upon energy considerations. As loading remains constant, strain energy in quasi-statically loaded beam equals vibrating energy in vibrating beam, damping included. When computing vibratory energy author considers 2- and 4-node symmetrical and 3- and 5-node antisymmetrical modes of vibration. Only bending energy due to inertia forces are considered. Available experimental evidence is stated to suggest that the major 2-node mode predominates, which means that slam loads were applied very close to bow end or higher modes were quickly damped out. Results of computations are compared with earlier works and are considered at least as reasonable as earlier results.

A consideration of vibrating beam with rectangular cross section in elastoplastic range concludes the paper.

E. R. Steneroth, Sweden

5782. Wah, T., A theory for the plastic design of ship plating under uniform pressure, *J. Ship Res.* **4,** 2, 17–24, Nov. 1960.

Analysis of plates of length-width ratio ≥ 2 is made by assuming the plate to be infinitely long. Earlier works are based on this approach and the approximation is considered good. Author therefore treats a unit width of plating. Plate material is assumed to behave as a perfectly plastic solid. Investigation is confined to plates clamped at the edges. The differential equation governing deflection, large compared to plate thickness, is integrated under consideration of different boundary conditions. Study takes into account effects of initial deflections, initial locked-in moments at edges, and displacements of edges in plane of plate. As particular cases author studies combinations of above effects; loading, unloading and residual deflection of unloaded plate are discussed. Discussion of significance of various equations developed and numerical examples are promised to appear later in the same Journal.

Author does not seem to be aware of Young's work on similar subject. E. R. Steneroth, Sweden

5783. Brumfield, R. C., Factors influencing the size and weight of underwater vehicles, *ARS J.* **30,** 12, 1152–1160, Dec. 1960.

Author breaks the weight of an underwater vehicle into the sum of a pay load weight; a structure weight, proportional to the vehicle volume; a propelling machinery weight, proportional to the two-thirds power of vehicle volume and related to the speed, drag coefficient and efficiency of the propulsion system; and a propellant weight also proportional to the two-thirds power of vehicle volume and related to range in addition to speed, drag and efficiency. In a similar manner he breaks down the vehicle volume into the same groupings plus a void space. Working with the equations thus formed he develops functions for their solution and coefficients for their optimization and applies them to optimizing a thermal-engine-propelled and an electrically propelled torpedo for a specific stern chase. The optimum ratio of torpedo speed to target speed for minimum missile weight in this case is about 1.2.

F. E. Reed, USA

Friction, Lubrication and Wear

(See also Revs. 5178, 5374, 5666)

5784. Vollheim, R., Calculation of wear in radial and axial impellers (in German), *Maschinenbautechnik* **9,** 10, 524–530, Oct. 1960.

Paper is contribution to wear problem of turbomachinery blades from the standpoint of dust particle conveying. Effects of well-known wear parameters (incidence, velocity, size, materials) on wear rate are discussed. Author eliminates as variables for his investigation dust particle size and shape, relative hardness of materials, etc., by considering only specific combinations of blade and particle materials. He suggests further wear testing for different blade-particle combinations, particle sizes, velocities, incidence angles, etc. Flow analysis, based on integration of equations of motion and use of Stokes law, results in determination of approximate particle trajectories in radial and axial impellers, as well as (in closed form) for the inlet section of the former. This leads to approximate methods of calculating wear parameters. Author lists requirements for minimizing wear, such as dust collection, avoidance of local dust concentration, low velocities, low incidence, provision of guide vanes in elbows, etc. Some of these, however, lead to design contradictions. Author claims that method could be used for wear prediction if and when sufficient experimental wear diagrams, ash analyses, and investigations of particle trajectories become available. In the meantime, its values lies in the interpretation of observed wear phenomena.

T. Ranov, USA

5785. Crook, A. W., Some studies of wear and lubrication, *Wear* **2,** 5, 364-393, Aug. 1959.

Author presents general review of experimental work done at Aldermaston Laboratories. First section is devoted to unlubricated sliding of metals. At nominal loads, wear was directly proportional to load and distance traveled. Increased loads resulted in sharp transition in wear due to breakdown of oxide films and subsequent metallic welding. Radioactive tracer techniques and studies of metallurgical transformations were used to define wear processes.

Second section describes lubrication work on rolling disks machine. Existence of hydrodynamic film was demonstrated and measurements of film thickness, by rate of oil flow, are described. Surface temperatures are main criteria in determining film thickness. Importance of run-in was demonstrated in preventing pitting and scuffing.

Appropriate references to original detailed work are given.

S. F. Murray, USA

5786. Hayama, F., Wear properties of brass (in English), Castings Res. Lab. Rept., Waseda Univ. no. 10, 63-81, 1959.

V-notch plate brass specimens were rubbed against a 0.7% carbon-steel shaft at speeds up to 150 cm/sec. The initial coefficient of friction rose from 0.2-0.4 to 0.6-0.95 during an initial period of "oxidized" wear with a low wear rate. This high friction was followed by rapid "adhesion" wear during which friction slowly decreased.

Cu_2O was the predominant wear product during oxidized wear. The approximately 2-micron thick layer formed on the steel during adhesion wear contained metallic particles ranging in size from 0.02 to 0.4 mm. These were estimated to be 45% copper oxide by weight.

α-brass was strengthened by workhardening to give a decreasing wear rate. Cold rolling of 60:40 brass gave some reduction in friction. Decreasing friction at higher speeds was attributed to higher surface temperatures with faster oxide formation.

E. R. Booser, USA

5787. Calhoun, S. F., Antiwear and extreme pressure additives for greases, *ASLE Trans.* **3,** 2, 208-214, Oct. 1960.

Twenty-nine additives were evaluated for their antiwear and extreme pressure properties when incorporated in various percentages in lithium soap-mineral oil greases. The percentages of the principal antiwear and extreme pressure-inducing elements sulfur, chlorine, phosphorus and lead were determined. The most promising ones were further evaluated in commerical greases and in inorganic thickened diester greases. Evaluations were based upon the four-ball wear and EP, the Falex, and the Timken testers.

Results indicate that phosphorus imparts antiwear properties while sulfur, chlorine, and lead give EP properties to greases. Combinations of additives would enhance both properties. Increase in the additive concentration gave increased values to the results. The type of grease had an effect upon the efficiency of the additive, thus indicating the need to fit the additive to the type and intended use of the grease.

From author's summary

5788. Zeman, K. P., and Coffin, L. F., Jr., Friction and wear of refractory compounds, *ASLE Trans.* **3,** 2, 191-202, Oct. 1960.

High-temperature propulsion systems using refractory compounds in moving parts require low friction and wear as well as high-temperature strength, hardness, oxidation resistance and thermal shock strength. Authors conclude that (a) the ratio of fracture strength to hardness of the refractory compounds tested (borides, carbides, nitrides and silicides and oxides of several metals) must approach that of bearing alloys in order to avoid bulk shearing and abrasion, and (b) the formation of reaction products with air serves as an effective influence on interfacial sliding over a limited temperature range.

Crossed cylinder experiments were conducted in air from room temperature to 2000 °F with a normal load of 2 lbs and a rotation speed of 14 to 15.7 rpm. Couples having complete solid solubility showed a friction coefficient greater than 0.65 and in some instances larger than 0.80. The wear scar diameters were greater than 1.5 mm. Whereas couples having no solid solubility known or predicted showed coefficients less than 0.5 in some cases and wear scar diameters less than 1.2 mm, there were exceptional cases giving friction coefficients as high as 1.00. In a couple of SiO_2 rotating against Al_2O_3 which had no solid solubility but was capable of forming an intermediate compound, the coefficient of friction varied from 0.30 to 0.76 and the wear scar diameter varied up to 2.4 mm, but above 1400 °F a chemical reaction appeared to influence the results.

Authors show several curves of average friction coefficient, wear scar diameter and hardness versus temperature. One plot shows the coefficient versus ZN/P for B_4C rotating against B_4C where N is rpm, P is load in lbs and Z is in centipoises for temperatures from 1400 °F to 1900 °F. Authors do not state how Z was determined. This is an excellent contribution to the scanty information on friction and wear at elevated temperature.

H. Majors, Jr., USA

5789. Loeser, E. H., Bench test of cam and tappet wear in additive oils, *ASLE Trans.* **3,** 2, 184-190, Oct. 1960.

Authors assess results on the smooth wear of automotive cams and tappets in bench tester originally developed for evaluating performance of engine oils containing various anti-scuff additives. They demonstrate a promising correlation with similar results obtained both in dynamometer and field tests.

H. Blok, Holland

5790. Dorinson, A., and Broman, V. E., Extreme-pressure lubrication and wear. The influence of rubbing speed on metallic wear at two contact pressures, *ASLE Trans.* **3,** 2, 176-183, Oct. 1960.

The wear of steel against steel lubricated with white oil was studied at two contact pressures, 155,000 psi and 70,000 psi, in the rubbing speed range 100-1000 ft/min. The time-dependent wear curves were multistage in character, showing first a sharp rise in the amount of wear, next a levelling-off and then transition to rapid wear again. Some of the curves had a second levelling-off phase. The data were examined also in terms of the distance traversed at the various speeds. No clear cut conclusion about the influence of rubbing speed was achieved by this latter method of treatment. It is shown on theoretical grounds that examination of the data with respect to time-dependence is the more revealing treatment. From authors' summary by T. Ranov, USA

5791. Halling, J., A crossed-cylinder wear machine and its use in the study of severe wear of brass on mild steel, *Wear* **4,** 1, 22-31, Jan./Feb. 1961.

This paper describes a crossed-cylinder type of wear machine which is designed for use in conjunction with a standard center lathe. The machine may be employed in the following methods of testing:

(1) The test specimen at rest in contact with the rotating cylinder.

(2) The test specimen being traversed along the axial direction of the rotating cylinder.

(3) Tests similar to (2) where a cutting tool prepares a freshly machined surface at a fixed time interval ahead of the wear test.

Results for these methods of testing are given for the severe dry wear of a 60/40 brass rubbing on mild steel. For tests of type (1) the wear rate is initially constant and then increases owing to the effect of transferred metallic films. This type of behavior is not

noted for tests of type (2). In tests of type (3) it is observed that the wear rate increases as the time interval between cutting and testing decreases and that marked intermittent seizure is also apparent.

From author's summary

5792. Trenkler, H., Contribution to the problem of wear by gases containing grit of Schicht axial flow fans (in German), *Brennstoff-Wärme-Kraft* **12**, 12, 530–536, Dec. 1960.

Investigations are described which aim at explaining different behavior toward wear of axial induced draught fans operating with different steam generators at the same power station. It was possible to establish that the design features of the fan wheel have a greater influence on blade wear than the other factors known to be effective when dust containing gases are handled. The conclusion is that the Schicht axial fan, which is in many ways a good unit, has its limit with a certain maximum head. When handling gas containing dust this limit is determined by sensitivity toward wear rather than by the pressure coefficient which can be reached at a certain circumferential velocity.

From author's summary

5793. Capriz, G., On some dynamical problems arising in the theory of lubrication (in English), *Riv. Mat. Parma* (2) **1**, 1–19, 1960.

This is a highly mathematical paper which is difficult to follow because of the lack of a nomenclature. Solution of Reynolds equation for small eccentricities is presented which leads to standard results for onset of half frequency whirl. Solution for whirls of large amplitude for an infinite bearing are also presented.

W. J. Anderson, Jr., USA

5794. Tipei, N., Effects of fluid film pressure on hydrodynamic lubrication, *ASLE Trans.* **3**, 2, 277–280, Oct. 1960.

A plane bearing of infinite width is considered; the lubricant's density and viscosity are taken to depend exponentially on the pressure; a solution of the Reynolds equation is found and is compared with the known solution which is valid when the lubricant is incompressible and isoviscous. It is found that the effects of compressibility are particularly marked when the ratio of inlet to outlet film thickness approaches unity (and obviously also when speed and compressibility coefficient are large).

G. Capriz, England

5795. Tipei, N., and Constantinescu, V. N., Generalization of Reynolds equation for the study of lubrication in the turbulent region (in French), *Rev. Mécan. Appl.* **5**, 3, 367–370, 1960.

Taking as a point of departure the previously established relations between the flow of lubricant, the pressure gradient, and the Reynolds number, authors deduce the pressure equation in the case of lubrication in the turbulent region with both incompressible and compressible fluids.

From authors' summary by J. A. Lewis, USA

5796. Bauer, W. H., Finkelstein, A. P., and Wiberley, S. E., Flow properties of lithium stearate-oil model greases as functions of soap concentration and temperature, *ASLE Trans.* **3**, 2, 215–224, Oct. 1960.

Lithium stearate-oil greases having 4, 8, and 12% soap were prepared and flow properties of the greases were investigated at 0, 25, and 37.8 C. Flow data were obtained with a cone and plate viscometer equipped with automatic programming and recording of shear stress versus rate of shear, and of shear stress versus time at selected shear rates. Flow curves, shear stress versus shear rate, were obtained for an initial and a repeat 300-sec cycle of shear with maxima of 1520 sec^{-1} and of 15,200 sec^{-1}. Flow curves were measured for highly worked samples, previously sheared at 19,000 sec^{-1} for 1000 sec. The rate of change of shearing stress required to maintain a constant rate of shear was measured at nine shear rates in the interval from 190 sec^{-1} to 19,000 sec^{-1}. Similar flow measurements were made on greases containing stearic acid additives. Initial flow resistance, ascribed to soap structural elements, showed temperature and concentration dependence differing from that of the sheared soap, and was destroyed by continued shear or addition of stearic acid. Flow resistance of the sheared samples was dependent on both the magnitude of the shear rate and the time of subjection to the shear.

From authors' summary

5797. Wisander, D. W., and Johnson, R. L., A solid film lubricant composition for use at high sliding velocities in liquid nitrogen, *ASLE Trans.* **3**, 2, 225–231, Oct. 1960.

Solid-lubricant-containing compositions can be of value as films and solid bodies for bearing and seal surfaces in low-temperature liquefied gases. An experimental composition including polytetrafluoroethylene (PTFE), an epoxy resin, and lithium-alumina-silicate was studied in friction, wear, and endurance experiments in liquid nitrogen (−320 F). This composition was formulated to approximate the thermal expansion of metals used in cryogenic systems. Hemisphere (3/16 −in. radius) rider specimens were used and in most experiments the load was 1000 g.

Films (0.005-in. thick) on disk specimens gave good endurance life, low rider wear, and desirable friction ($f = 0.02$ to 0.07). They functioned at a higher sliding velocity (no failure at 16,000 ft/min) with copper rider specimens than with stainless steel riders (failure at 9000 ft/min).

Solid rider material of the experimental composition had good friction and wear properties at sliding velocities above 4000 ft/min. It is important to use the experimental composition with mating materials having good thermal conductivity.

From authors' summary

5798. Jacobson, M. J., and Saibel, E. A., The finite partial fitted journal bearing, *ASLE Trans.* **2**, 2, 242–247, Oct. 1959.

The solution of Reynolds equation for cylindrical journal bearings of finite length can be expressed as a series of products of a hyperbolic function and a Heun function [L. N. Tao, AMR **13**(1960), Rev. 6134]; for fitted bearings the latter function reduces to a hypergeometric function [M. J. Jacobson, AMR **12**(1959), Rev. 2174]. Through numerical evaluation of the series, special cases can be studied; here fitted partial bearings (arc of 90° and of 120°; width-to-diameter ratio equal 1/2) are considered. For the calculation of load-carrying capacity the regions of negative pressure are disregarded.

It is found that the infinite bearing approximation usually overestimates (grossly sometimes) the load-carrying capacity. Unfortunately the results quoted are too few to gain an over-all picture of the operation of the bearing; to confirm, for instance, the rule that, for safety, the load must point to the downstream half of the bearing.

G. Capriz, England

5799. Ozdas, M. N., Short journal bearings subjected to dynamic loads (in English), *Bul. Istanbul Tekn. Univ.* **12**, 99–114, 1959.

Reynolds equation with short bearing approximation is solved for case of sinusoidal load without rotation, assuming zero altitude angle, and for case of rotating load of constant magnitude. For the latter case, load capacity is zero when load rotates at half the journal speed. For sinusoidal load case results predict a higher eccentricity than infinite bearing theory.

W. J. Anderson, Jr., USA

5800. Tallian, T., Gustafsson, O. G., and Walp, H. O., Plastic yielding and vibrations of rolling element bearings, *ASLE Trans.* **3**, 2, 244–254, Oct. 1960.

A high degree of resistance to plastic deformation at the contacts between rolling bodies and rings is required in bearings used for equipment that must be quiet running. It is shown that, within practical bearing design limits, this resistance is primarily a function of material structure variables that affect the elastic limit.

Hardness, as measured by Rockwell or Diamond Pyramid methods, is a primary variable but, in itself, an inadequate measure of this resistance. A test method is described giving good correlation with conditions causing plastic deformation of bearings in applications. The effects of residual stress, surface conditions and contact configuration are discussed. It is shown that bearings with substantially improved resistance to plastic indentation are obtainable by the use of appropriate heat treatment.

From authors' summary by H. Blok, Holland

5801. Glaeser, W. A., The performance of heavily loaded oscillating roller bearings from 300 F to 600 F, *ASLE Trans.* **3,** 2, 203–207, Oct. 1960.

Load-life characteristics were statistically assessed for intermittently grease-lubricated, self-aligning roller bearings. Of three steels tested, only M-2 tool steel and 440 C stainless steel, when applying a silicone base grease, proved satisfactory up to the highest test temperature. Remarkably enough, although various failure modes were encountered, the failure distribution frequencies fairly closely fitted the Weibull distribution originally set up for surface fatigue. H. Blok, Holland

5802. Otsuki, Y., On the experiment of high speed roller bearings with oil-mist lubrication, *Bull. JSME* **4,** 13, 148–153, Feb. 1961.

The turbine roller bearings of a turbojet-engine operate under the severe condition of high speed, high temperature and heavy load. Therefore there are many problems in practical use.

The object of this experiment is to obtain fundamental data on whether oil-mist lubrication is applicable in practical use or not. Experiments are carried out under various severe conditions of speeds, temperatures and loads.

Performances by oil-mist lubrication are also compared with those by oil-jet lubrication. As a result of experiments, the rise of bearing temperature is found to be a function of rotating speed and air quantity independent of oil quantity and load. It is understood that the air in oil-mist lubrication has the important role of a cooling medium and in this respect oil-mist lubrication is better than oil-jet lubrication. From author's summary

5803. Burr, A. H., The effect of shaft rotation on bearing temperatures, *ASLE Trans.* **2,** 2, 235–241, Oct. 1959.

Heat-transfer data from recent studies of rotating cylinders are utilized in heat balance method of predicting oil film temperatures for shaft and plain bearing combinations. Good agreement is obtained between calculated temperatures and experimental values. It is shown that heat dissipation from a rotating shaft may be much greater than that from a stationary shaft and from bearing housings, and it may be a major path for heat dissipation in certain cases.

From author's summary by W. J. Anderson, Jr., USA

5804. Fein, R. S., Transition temperatures with four ball machine, *ASLE Trans.* **3,** 1, 34–39, Apr. 1960.

"Flash temperature" heat balance analyses were applied to transition temperature data from a four-ball wear tester and a pin-on-disc unit. The calculated surface temperature at onset of catastrophic wear increased with decreasing ratio of load to speed. With a paraffinic mineral oil and with 1/3 mole-% capric acid or stearic acid in cetane, interesting similarities existed between bench tests and general observations for gear sets.

E. R. Booser, USA

Letters to the Editor

5805. Re: AMR **14** (1961) Rev. 3177: **Yih, C.-S., Gravity waves in a stratified fluid, J. Fluid Mech. 8, 4, 481-508, August, 1960.**

This review, while perhaps not consciously biased, is nevertheless inaccurate. The reviewer stated flatly that the results are not new, whereas many results, including most of the results stated in the second paragraph of the review, are new, and many others have a greater generality which is new, as I stated in the paper. Furthermore, where else does one find the simple result regarding the effect of compressibility, or the relationship between the wave velocities in a stably stratified fluid and the rate of amplification of a disturbance when the stratification is inverted and therefore made unstable? In this connection, the opening sentence of the review is also inaccurate because it implies that only stably stratified fluids are treated. It is also demonstrated in the paper in a general way that for a multi-layer system with slight continuous stratification in each layer, the interfaces remain essentially flat for internal-wave motion. Can Dr. Scorer tell us where else this general demonstration can be found?

C.-S. Yih, USA

5806. Re: AMR **14** (1961), Rev. 1264: **Dabrowski, R., Simultaneous bending and torsion of thin-walled bars (in German), Stahlbau 29, 4, 104-111, Apr. 1960.**

Reviewer wishes to correct the last sentence from "Reviewer considers that application of author's equations is more time-consuming than using diagrams by Petterson.", to "Reviewer considers that application of author's equations is no more time-consuming than using diagrams by Petterson."

G. G. Meyerhof, Canada

Books Received for Review

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BAKER, H. D., RYDER, E. A., AND BAKER, N. H., Temperature measurement in engineering, Vol. 2, New York, John Wiley & Sons, 1961, vii + 510 pp. $13.

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